Assessing the market niche of Eurasian rail freight in the belt and road era

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Abstract

Purpose – This paper presents an overview of the recent development of Eurasian rail freight in the Belt and Road era and further evaluates its service quality in terms of transit times and transport costs compared to other transport modes in containerised supply chains between Europe and China.

Design/methodology/approach – A trade-off model of transit time and transport costs based on quantitative data from primary and secondary sources is developed to demonstrate the market niche for Eurasian rail freight vis-a-vis the more established modes of transport of sea, air and sea/air. In a scenario analysis, further cargo attributes influencing modal choice are employed to show for which cargo type Eurasian rail freight service is favourable from a shipper's point of view.

Findings – At present, Eurasian rail freight is about 80% less expensive than air freight with only half of the transit time of conventional sea freight. Our scenario analysis further suggests that for shipping time-sensitive goods with lower cargo value ranging from $US1.23/kg to $US10.89/kg as well as goods with lower time sensitivity and higher value in a range of $US2.46/kg to $US21.78/kg, total logistics costs of Eurasian rail freight service rail is cheaper than all other modes of transport.

Practical implications – As an emerging competitive solution, Eurasian rail freight demonstrates to be an option beneficial in terms of transport cost, transit time, reliability and service availability, which offers a cost-efficient option enabling shippers to build up agile and more sustainable supply chains between China and Europe.

Originality/value – Our study firstly provides a comprehensive assessment of present Eurasian rail freight including a thorough comparison with alternative modes of transport from a shipper's point of view.

Keywords Belt and road initiative, Eurasian land bridge, Trans-Siberian railway, Container block train, Service quality, Transport cost, Transit time, Cargo value, Value to weight ratio

Paper type Research paper

1. Introduction

In 2013, the term 'Belt and Road' first came into the spotlight as China's masterplan initiative to revive the Ancient Silk Road was announced by Chinese President Xi Jinping. Following the National Development and Reform Commission (NDRC) (2015), the now called 'Belt and

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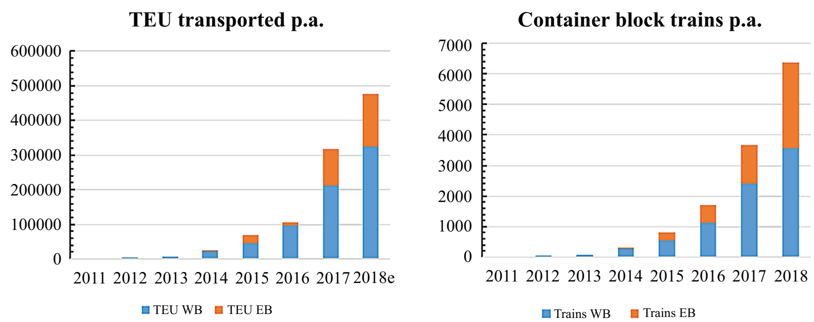
Road Initiative' (BRI), is often communicated as a 'National Vision' and 'Foreign Strategy' towards regional cooperation, and it is also mentioned about infrastructural project construction and investments (Van der Leer and Yau, 2016).

The BRI includes two major parts – the New Silk Road Economic Belt and the 21st-Century Maritime Silk Road (hereinafter referred to as the Belt and the Road respectively). Both represent a network of ports, railways, roads, pipelines and utility grids connecting China with Central Asia, West Asia and parts of South Asia, Europe and Africa (NDRC, 2015; Tian, 2016). Although the BRI is more than just physical connections (Tian, 2016), it provides a blueprint framework for Chinese diplomatic, commercial and foreign infrastructure policies to get access to new markets for trade and investments (Van der Putten and Meijnders, 2015). The aims of the BRI are to (1) promote connectivity of Asian, European and African continents via land, sea, and air, (2) establish and strengthen regional cooperation and partnerships among the countries along these routes and (3) facilitate the flow of economic resources and integration of markets (Song, 2015).

The Belt part of BRI revives the Ancient Silk Road as a land route for trading between the East and the West – not by camel or donkey but by railway (Otsuka, 2001), and goods remain in the same container for the entire intermodal journey (Rodrigue, 2017). Currently, the Eurasian rail freight only takes a small share of the total transport volume between China and Europe (Bucsky, 2019). However, with the rapid growth of freight transport on the rail routes along the Belt, the Ancient Silk Road trading routes are coming back to life again as container block trains have emerged as an alternative transport mode there in recent years (see Figure 1). In 2019, it is reported that there are 8,225 container block trains with 725,000 TEU transported on the Belt (MOFCOM, 2020).

In response to the emergence of Eurasian rail freight, most research studies on Eurasian rail freight and the BRI are policy studies or consultancy work (Davydenko *et al.*, 2012; UNECE, 2012, 2017; Rastogi and Arvis, 2014; Ardunio, 2016; Galushko, 2016; UIC and Roland Berger, 2017; Jakóbowski *et al.*, 2018; Vinokurov *et al.*, 2018). In addition to this, a rapidly increasing number of scholarly contributions deal with the competitiveness of container block train operations between China and Europe like Rodemann and Templar (2014), Besharati *et al.* (2017), Chen *et al.* (2017), Seo *et al.* (2017), Yang *et al.* (2018a, b), Wiegmans and Janic (2019), Jiang *et al.* (2018, 2019), Wen *et al.* (2019), Bucsky (2019), Dunmore *et al.* (2019), Lu *et al.* (2019), Kundu and Shen (2019) or Feng *et al.* (2020) as well as some more in the Chinese language as discussed in Liu *et al.* (2018) and Lee *et al.* (2018). Other less related works are Song *et al.* (2011), Song and Na (2012), Tsuji (2013) or Kim *et al.* (2020) focusing on multimodal freight transports via Trans-Siberian Railway (TSR) with a short sea leg from China, South Korea and/or Japan to Russian Far East. Another stream of literature deals with a comparison



Source(s): CRCT (2019), Modor Intelligence (2019), Zhang (2019)

Figure 1.
China–Europe rail freight continues to soar

of Northern Sea Route (NSR) with Suez Channel Route (SCR) and TSR or other routes of the Belt part of BRI from/to South Korea (Moon *et al.*, 2015; Zeng *et al.*, 2020).

However, when comparing alternative transport modes, only a few authors go beyond just comparing the Belt and Road part of BRI by including air cargo (Seo *et al.*, 2017; Dunmore *et al.*, 2019; Kundu and Shen, 2019) or road haulage (Rodemann and Templar, 2014). Furthermore, while almost all studies deal with transport costs or freight rates solemnly on container shipment level, they do not take different cargo values and/or service quality needs by shippers explicitly into consideration with the notable exception of recent works by Yang *et al.* (2018a, b), Bucsky (2019), Dunmore *et al.* (2019), Lu *et al.* (2019), Kundu and Sheu (2019) or Zeng *et al.* (2020).

In contrast, this paper takes a shipper's perspective on the modal choice to assess the competitiveness of rail freight with a wider range of alternative transport modes, where service quality attributes and cargo value are considered as a novel contribution from the previous studies. A comparative analysis with a trade-off model based on transit time and transport costs is developed to evaluate the market niche for Eurasian rail freight vis-a-vis the more established modes of transport, namely sea, air, and sea/air. In a scenario analysis, further cargo attributes influencing the modal choice are employed to further investigate for which cargo type Eurasian rail freight service is favorable. In this respect, this paper contributes to the knowledge base of Eurasian multimodal freight transport research studies by incorporating service quality and cargo value of Eurasian rail freight in the Belt and Road era.

The remainder of this paper is organised as follows. Section 2 presents a comprehensive overview of recent literature on Eurasian rail freight developments. In Section 3, service quality issues of Eurasian rail freight are highlighted to provide a basis for the comparative analysis in form of a trade-off model of transport costs and transit times compared with other modes of transport followed by a scenario analysis based on cargo type. The results of the trade-off model of transport costs and transit times and the scenario analysis based on cargo type demonstrate the market niche for Eurasian rail freight services thoroughly discussed in Section 4. Finally, Section 5 concludes with managerial implications and limitations of this study, and future research agendas are also proposed.

2. Background and service characteristics

In this section, we aim to present an overview of the recent developments concerning Eurasian rail freight operations based on literature available in English, Russian and Chinese language and complemented by interviews with main players being active on this market. First, a detailed geographic overview of the two major routes and three corridors on the Belt between China and Europe will be introduced. Following a review of the Eurasian rail freight services in terms of its current routing development, types of goods transported, market players, bottlenecks in operations and the hot-debated governmental subsidy issue. These service characteristics of Eurasian rail freight will provide a basis for us to construct the comparative and scenario analysis in this study.

2.1 Eurasian rail freight transport in the Belt and Road era

The Belt part of BRI connects cities in Europe with Russian Far East and China by railway lines running through East Asia, Central Asia, Southern Russia, Eastern Mediterranean, Arabian Peninsula and Europe (Lin, 2011). Given that at least some parts of this Belt follow the same track with the Ancient Silk Road, thus it is also called 'New Silk Road' or 'Modern Silk Road' (NDRC, 2015). The Belt includes two major rail land bridges between Europe and Asia as shown in Figure 2, namely:

(1) *The Trans-Siberian Railway* (TSR, or First Eurasian Land Bridge) served as the main land bridge between Russian Far East and Western Europe from the late 1960s until

the early 1990s (Lilliopolou *et al.*, 2005; Pieriegud, 2007). The TSR starts from the Russian Far East Pacific seaports Vladivostok and Nakhodka running west through Russian Federation to Moscow, and further reaches European countries such like Finland, Latvia and Poland through different rail routes (OSJD, 2019), at the east end, maritime links connecting the aforementioned Russian seaports with China, South Korea or Japan are also considered as a natural extension of the intermodal transport routes of this traditional Eurasian land bridge (Song *et al.*, 2011; Song and Na, 2012; Tsuji, 2013; Moon *et al.*, 2015; Zeng *et al.*, 2020; Kim *et al.*, 2020).

(2) *The New Eurasian Land Bridge* (NELB, or Second Eurasian Land Bridge) originally spans from the Pacific port of Lianyungang in China running through China, Kazakhstan, Russian Federation, Belarus to Rotterdam in the Netherlands (Islam *et al.*, 2013; OSJD, 2019) with a variety of intermodal terminals as points of origin and destination in between.

The abovementioned TSR and NELB are the current two main routes connecting Asia to Europe (Sárvári and Szeidovitz, 2016). Notably, these two major Eurasian land bridges consist of several train routings across various countries with individual branch lines that partially share the same main line sections as well (Rodemann and Templar, 2014). They can be described as follows:

The Northern Corridor provides three alternative branch lines connecting China and Europe via TSR (Islam *et al.*, 2013; Galushko, 2016; OSJD, 2019), namely:

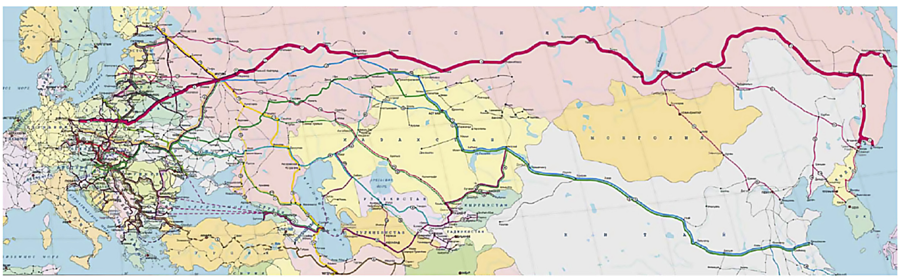
(1) China – TSR via Alashankou/Dostik and transit through Kazakhstan (Kazakh route)

(2) China – TSR via Erenhot/Zamyn-Uud and transit through Mongolia (Mongolian route)

(3) China – TSR via Manzhouli/Zabajkalsk (Manchurian route)

Trains on this route start in China, head via one of the three border crossings for the TSR toward the west and enter European Union at Brest/Malaszewicze, Siemianovska/Svisloch, Kuznitsa/Bruzhi or (but to much less extent) via Slovakia, Hungary, Estonia, Latvia, Lithuania, Finland and/or the Russian exclave of Kaliningrad (van Leijen, 2018b; OSJD, 2019; UTLC, 2020). However, it is noted that the classic TSR line starting in Vladivostok or Nachodka is not considered in the BRI development strategy (Sárvári and Szeidovitz, 2016).

The Central Corridor provides an alternative east-west route through Kazakhstan and Russian Federation to connect China and Europe called NELB. Trains on this route cross the Chinese – Kazakh border at Alashankou/Dostik or Altynkol/Khorgos and usually run further west via railway lines south to the TSR towards the aforementioned border crossings to



Source(s): OSJD,2009

Figure 2.
Route of the trans-siberian railway (red) and the New Eurasian land bridge (green) (OSJD, 2009)

European Union. This route is the main target of the Belt in the BRI (Sárvári and Szeidovitz, 2016).

Meanwhile, it is worth mentioning that there is *the Southern Corridor* called the Trans-Caspian International Transport Route (TITR, http://titr.kz/en) upcoming which runs through Kazakhstan, the Caspian Sea, Azerbaijan and Georgia further to Turkey, Ukraine or European countries. However, this routing requires at least one ferry trip across the Caspian Sea and transcends the Caucasus towards the Black Sea or Turkey to reach Europe and these multiple border crossings, ferry trips, and current geopolitical issues in the Caucasus region make it rather unattractive (Sárvári and Szeidovitz, 2016; Bucsky, 2019).

2.2 Service characteristics of Eurasian rail freight

In March 2011, China launched the China Railway Express (CR Express) freight service to enhance connectivity with markets in Central Asia and Europe along the Belt of BRI (Luo, 2017; Jiang *et al.*, 2018). Originating from different parts of China, these container block trains have different routings: trains starting in the western and central part of China, namely Urumqi, Chongqing, Chengdu, Wuhan or Xi'an go via Alashankou or Altynkol to Europe, whereas trains from the east coastal and northern region such as Putian, Shengyang, Suzhou or Zhengzhou tend to leave China via Manzhouli or Erenhot and follow the TSR to Europe (Luo, 2017; OSJD, 2019; CRCT, 2019).

Following OSJD (2019), Zhang (2019) and Bucsky (2019) most of the traffic goes along the Kazakh route. Here, the joint-stock company United Transport and Logistics Company – Eurasian Rail Alliance (UTLC) is regarded as the domain player offering services for transportation of containers by regular container block trains between China and Europe through the transit countries of Kazakhstan, Russian Federation and Belarus (UTLC, 2020).

By the end of 2018, CR Express run 65 dedicated block train lines connecting 56 Chinese cities with 49 cities in 15 European countries (China Railway Supply Chain and Logistics, 2019). The main intermodal terminals on the European side were Malaszewicze, Warsaw, Duisburg or Hamburg, with some dedicated block trains also end at Budapest, Klaipeda, Lodz, London, Madrid, Muuga, Nuremberg, Pardubice, Riga, Rotterdam, Schwarzheide or Tilburg (CRCT, 2019; OSJD, 2019; Pomfret, 2019). New lanes with many more new origins in China and destinations in Europe announced from time to time in media.

However, Eurasian rail freight service operations have some idiosyncratic features concerning types of goods transported, major market players engaged in block train operations and bottlenecks and heavy subsidisation of freight rates that should be taken into consideration.

2.2.1 Types of goods transported. Currently, most of the goods transported on these Eurasian rail freight routes between China and Europe are mainly machinery and equipment, vehicles and spare parts, household appliances, food and beverages, garment and electronic products (Wang, 2017; Bucsky, 2019), see Table 1. The type of cargo transported by rail

Cargo value	Westbound (China – Europe)	Eastbound (Europe – China)
High-value goods	Machinery and equipment, vehicles and spare parts, electronic products	Machinery and equipment, vehicles and spare parts, luxury garment and leather goods
Low-value goods	Luggage, stationery, handicrafts, garment, household appliance, coffee beans, tea, textiles, chemical products, flowers and trees	Wine, beer, milk, meat, olive oil, cosmetics, timber

Source(s): Wang (2017)

Table 1. Type of goods shipped on China Railway Express

gradually shifted to higher value-added goods (Sárvári and Szeidovitz, 2016), whereas the types of cargo on the return trips from Europe to China are high-value machinery and equipment, vehicles and spare parts, as well as luxury goods, foods and beverages.

2.2.2 Major market players engaged in Eurasian container block train operations. It is important to understand who the major players in this Eurasian container block train market are. Apart from the aforementioned CR Express and UTLC, container transports along these Eurasian rail freight corridors as shown in Section 2.1 comprise a variety of different market

Market player	Function	Example
Shipper	Cargo owner, clients of forwarders	Siemens-Fujitsu, BSH, BMW, HP*, Apple*, Acer*, Foxconn*, Haier*, Samsung*, Audi*, Volkswagen*, Volvo*, Decathlon*etc.
Forwarder	Organise transport on behalf of shippers	Kuehne & Nagel, DB Schenker, DHL*, GEFCO*, HAL Logistics*, Cosco Logistics*, Sino Railway*, Sinotrans*, Kerry Logistics*, Pantos Logistics*, DSV*, Belintertrans*, Silvirom*, Gebr. Weiss*, Panalpina*etc.
Container operator	Container carrier, organise dedicated block trains or single container transports	InterRail Services, Russkaya Troyka, Hupac International Logistics, Far Eastern Transport Group (DVTG)*, Far East Land Bridge (FELB) *, China Railway Express (CR Express)*, Sino Railway*, Hunan Xiang Ou Express Logistics*, Hao Logistics*, YuXinOu Logistics*, Yiwu CF Intl. Logistics*, HLT Intl. Logistics Ningbo (H&T)*, Wuhan Asia–Europe Logistics (WAE) *etc.
National railway company	Provision of traction, infrastructure, wagons tariff policy	Russian Railways (RZD), Belarussian Railways (BC), Kazakhstan Railways (KZH)*, Chinese Railways (KZD)*, Deutsche Bahn (DB)*, Polish State Railways (PKP)*, Latvian Railways (LDZ) *, Railcargo Austria*
Affiliated company for container transport	Organise and operate intermodal transport on behalf of railways	DB Intermodal, TransContainer, KTZ Express*, United Transport & Logistics Company (UTLC)*, CRIntermodal*, China Railway Container Transport (CRCT)*, Trans Eurasia Logistics (TEL)*, YuXinOu Logistics*
Container owners	Own containers for own transport and/or leasing; shipping companies, leasing companies	Maersk, Evergreen, Seaco, China Railway Express*, Far East Land Bridge (FELB)*, TransContainer*, Far Eastern Transport Group (DVTG)*, Pantos Logistics*, China Railway Container Transport (CRCT)*etc.
Terminal operator	Handling of containers on behalf of container transport companies and container owners	Deutsche Umschlaggesellschaft Schiene-Straße (DUSS), TransContainer, Duisport*, Russian Railways (RZD)*, Far Eastern Transport Group (DVTG)*, CRIntermodal*, China Railway Container Transport (CRCT)*, PKP Cargo*, KTZ Express*
Railway agency	Book transport on behalf of train operators	Kaztransservice, Transrail, Belintertrans*
Customs agents	Customs clearance on behalf of forwarders	Far Eastern Transport Group (DVTG)*, PKP Cargo*, United Transport & Logistics Company (UTLC)*, TransContainer*, Pantos Logistics*, Belintertrans*

Source(s): Pieriegud (2007), Davydenko *et al.* (2012), updates by the authors indicated with "*"

Table 2.
Major market players in Eurasian rail freight container transport

players due to the railway systems spanning multiple countries and operators, which forms a complex contractual network (Davydenko *et al.*, 2012; UNECE, 2017; Jakóbowski *et al.*, 2018; Bucsky, 2019). Table 2 shows principle market players in Eurasian rail freight container transport as identified by Pieriegud (2007), Davydenko *et al.* (2012), and updated based on author's desk research and interviews with main players in the Eurasian rail freight market.

2.2.3 Heavy subsidisation of freight rates. To promote rail freight on the Belt and maintain normalised operation, operations of CR express under BRI are heavily subsidised (Bresharati *et al.*, 2017; Qiwen and Xianliang, 2017; Jiang *et al.*, 2018; Bucsky, 2019; Kundu and Sheu, 2019; Feng *et al.*, 2020), varying from $US1,000 to 7,000 per FEU (Wang, 2015; Jiang *et al.*, 2018).

Provincial and local governments in China provide a various amount of subsidies to railway operators. The amount of subsidy will be granted based on the block train booking forecast submitted by the operators (Jiang *et al.*, 2018) to cover the cost gap between rail and sea freight. For example, trains origining from inland cities such as Chongqing, Chengdu, Zhengzhou and Wuhan received higher subsides with an average of $US7,000 per FEU. Trains from coastal city Suzhou receive a lower subsidy of $US1,000 per FEU (Jiang *et al.*, 2018). Due to the imbalanced cargo volume, this subsidy even more heavily goes to covering the under-capacity running on the eastbound trip from Europe to China (Jiang *et al.*, 2018; EUCCC, 2020).

Such subsidies may distort the freight market, since the freight rate of CR express service is often lower than its cost, and sometimes as low as sea freight rate (Chen *et al.*, 2017; EUCCC, 2020). However, it is reported that the Chinese government plans to reduce the subsidy by 30% in 2020, and abolish it entirely by 2022 (EUCCC, 2020).

2.2.4 Bottlenecks in Eurasian rail freight operations. Operating long-haul container block trains across multiple countries in a short time is not easy, as complex legal environment, technical limitations, physical constraints, capacity limits and imbalanced cargo volumes post bottlenecks in Eurasian rail freight operations (Islam *et al.*, 2013; InterRail, 2017; Besharati *et al.*, 2017; Vinokurov *et al.*, 2018; Jakóbowski *et al.*, 2018). These bottlenecks are summarised in Table 3 along with improvements in the meantime.

3. Methodology

Employing a comparative analysis and a scenario analysis approach, the study is to examine the service quality of rail freight compared to the other current existing containerised transport solutions between China and Europe, namely sea, air, and sea/air transport modes. The sea/air concept is a multimodal transport of cargo by sea on its first leg followed by air which comes along with 'half the time half the cost' (Raguraman and Chan, 1994). Moreover, the service quality of rail freight and modal choice from the shipper's perspective are highlighted in this section to provide a basis for the comparative analysis in this study. A trade-off model based on transport cost and transit time and scenario analysis based on cargo value will be constructed based on transport costs and transit time, to compare the cost and time differences of sending a containerised shipment from China to Europe by sea, air, sea/air or rail respectively.

3.1 Service quality of freight transport

With the purpose to examine the service quality of rail freight with other alternative transport modes, it is important to understand the 'service quality' concept and provide definitions to clarify the research scope in this study. It is commonly agreed that service quality is characterised by customer's perception of service (Shainesh and Mathur, 2000), so that it can be defined as 'the difference between customer expectations of service and perceived service'

	Bottlenecks identified	Improvements
Complex legal environment	Differences in transport and customs law lead to arbitrary transport documentation and lengthy border crossing procedures (Kallas, 2012, Galushko, 2016, Jakóbowski *et al.*, 2018; Zhu and Filimonov, 2018)	The International Rail Transport Committee (CIT) established a combined CIM-SMGS consignment note as a commonly accepted transport document along the Belt route (Galushko, 2016) The foundation of the Eurasian Customs Union (EACU) including the Russian Federation, Belarus, and Kazakhstan in 2010 eased transit through these countries and China joined the TIR Carnet transit framework in 2017 which allows end-to-end transit operations (UIBE and IRU, 2017)
Technical limitations	Lack of unified standardisation (e.g. railway gauge) hinders the interoperability of railway systems (Galushko, 2016; Panova *et al.*, 2018) The technical infrastructure of railways en route such as double track lines or electrification might hinder an uninterrupted transport (Liu, 2014)	The wide-spread use of intermodal containers ease these interoperability issues considerably – but it still takes about 2–21 h to complete the trans-load for a container block train (UTLC, 2020)
Physical constrains	Extreme weather condition with minus 40°C in Siberia can be a challenge for many sensitive goods (Woods, 2015)	Containers for such block trains are equipped with thermal insulation and active temperature control systems whenever necessary (InterRail, 2017; UTLC, 2020)
Capacity limits	In China, a block train can carry around 55 FEUs, on the TSR up to 75 FEUs, while in Europe, they are usually limited to max. 44 FEUs, and also all freight trains have to give priority to passenger trains (Jakóbowski *et al.*, 2018) Limit on the structure gauge. This also prevents to transport containers double-stacked to add on capacity due to limited clearance	–
Imbalanced cargo volume	The number of westbound block trains is about three times of the eastbound ones (InterRail, 2017; Besharati *et al.*, 2017; Vinokurov *et al.*, 2018; Jakóbowski *et al.*, 2018)	A general trend towards a more balanced ratio of westbound and eastbound cargo volumes has been witnessed (Woods, 2015; InterRail, 2017). Since 2018, only block trains with more than 40 full containers are allowed to depart and are eligible for subsidies (van Leijen, 2018a)

Source(s): Authors' own

Table 3. Bottlenecks and improvements identified in the literature

(Shahin, 2006). Accordingly, when service quality is to be evaluated, the difference between the services that customers expect and the services perceived has to be examined.

To evaluate the service quality, the measurement method should be adopted to examine the difference between the services that customers expected and the services perceived. Measurement will be conducted to compare the changes in service quality, and also to identify the problems thus further improve service delivery (Shahin, 2006).

There are an array of factors and determinants to measure service quality (Prasad and Shekhar, 2010). The most commonly used metrics for measurement of service quality is called SERVQUAL, firstly proposed by Parasuraman *et al.* (1988). Five dimensions – tangibles, reliability, responsiveness, assurance and empathy – are used as basic instruments for service quality measurement to examine gaps between expectations and perceptions (Parasuraman *et al.*, 1988; Zeithaml *et al.*, 1990). Although the SERVQUAL instruments have been widely used and proven to be valid and reliable in different service contexts, they still need to be modified and adapted to reflect specific service settings (Prasad and Shekhar, 2010).

Based on the SERVQUAL metrics, RAILQUAL has been developed as a service quality scale to measure the rail service quality passenger transport with three additional dimensions – convenience, comfort and connection – added to the basic five SERVQUAL metrics (Prasad and Shekhar, 2010).

However, the 'RAILQUAL' metrics are used for measuring the quality of rail passenger service. This study focuses on examining the quality of rail freight service and very few published literature reports the use of SERVQUAL to assess the rail freight transport service.

To understand the service quality of freight transport, variables are identified by researchers in investigating shippers' freight service decision choice between different transport modes. Matear and Gray (1993) applied principal components analysis to explore the underlying structure of the service choice decision for shippers and freight suppliers when choosing between sea and air modes of transport (see Table 4). Five principal components – carrier, route, timing, price characteristics and control over other parties – have been considered as important factors in the modal choice.

Among these five principal components, Matear and Gray (1993) pointed out that frequency, reliability (i.e. punctuality concerning the time of arrival) and capacity (i.e. the availability of freight space) are the most important ones. Later on, Rodemann and Templar (2014), as well as Seo *et al.* (2017) confirmed that transport cost, transit time, as well as transit time reliability are the major modal choice decision criteria concerning goods transports between China and Europe.

3.2 Data collection

Quantitative data obtained in this study includes quotes of transport, transit time, the distance of each route for each mode on each route (see Table 5). To maintain the integrity and reliability of the data collection process, freight rates for rail, sea, air and sea/air were requested from major container operators or forwarders in Austria, Germany, China and Kazakhstan. Additionally, average freight rates for sea and air were retrieved from Freightos (http://www.freightos.com) and SeaRates (http://www.searates.com) as well as cross-checked with secondary data provided by Chen *et al.* (2017), Jiang *et al.* (2018), Dunmore *et al.* (2019) and Drewry Shipping Consultants (https://www.drewry.co.uk/). Both freight rates and transit times presented are averages based on a sample of quotations for each transport leg.

Principal component	Service attributes
Carrier characteristics	Arrival time; Fast response to problems; Handle special requirements and urgent deliveries; Good relationship with carriers
Route characteristics	Proximity to origin and destination; Optimised route choice
Timing characteristics	High service frequency; On-time collection and delivery; Short transit time
Price characteristics	Low price; Value for money price; Special offer or discounts
Control over other parties	Transport preference of trading partner; Documentation completed carrier

Source(s): Adapted from Matear and Gray (1993)

Table 4. Service attributes for service choice decision

Table 5.
Data collection summary

Data collected	Data type	Source	Collection method
Rail	FEU FCL freight rate for all possible routes from Asia to Europe Transit time along major corridors	European and Central Asian block train operators Chinese and Central Asian rail freight forwarders Secondary data from literature	Online enquiry Site visits, Skype and face-to-face interview Secondary data collection
Sea	FEU FCL freight rate and transit time from China to Germany	Freightos.com SeaRates.com World Container Index (WCI) by drewry	Online enquiry Secondary data collection
Air	Unit rate (per kg) and transit times from China to Germany	Freightos.com SeaRates.com East-West Air Price Index (API) by drewry	Online enquiry Secondary data collection
Sea/Air	Unit rate (per kg) and transit times from China to Germany	European freight forwarder Sea/air freight operator	Quotes request with freight forwarder Secondary data collection
Distance	The separate distance of each transport leg and the total distance of each route	SeaRates.com Ecotransit.org	Online enquiry

Source(s): Authors' own

Furthermore, a set of assumptions have been made to make the different modes comparable:

(1) Transport routes are all terminal-terminal intermodal, excluding local cartage service at both origin and destination. Accordingly, ancillary costs (i.e. fees for customs clearance, security checks, agency, insurance, document and container handling) are not included.

(2) Freight rate quotations for all modes of transport are for an FEU full container load (FCL) freight-all-kinds. The cargo transported in an FEU by sea and rail is assumed max. 20 tonnes, and for air and sea/air max. 10 tonnes. Concerning transport capacity, it is assumed that max. 45 FEU can be transported per block train, max. 3 FEU per airplane and 9,000 FEU or more per vessel by sea (Woods, 2015; Bucsky, 2019; Dunmore *et al.*, 2019).

(3) Transit times stated were as indicated by the freight operators or forwarders. However, delays caused by congestions at intermodal terminals, border crossing points, documentation handling processes still occur regularly (Galushka, 2016).

It is noted as all the primary data from major container operators or forwarders in Austria, Germany, China and Kazakhstan were collected during the period from 1 June to 31 July 2017. Due to commercial consideration, confidentiality and protection of personal data, the personal and company information in the data obtained were made anonymous in this study. Freight rate quotations and transit times stated may be subject to change due to the volatility of the freight rates in the marketplace. In this sense, the freight rates and transit times presented here reflect a 'snapshot' of the current market situation and need to be considered in a more general context. However, the Eurasian Rail Alliance Index (http://index1520.com/) demonstrates well, that freight rates by sea and rail, in particular, did not fluctuate as much over time since 2017. The same is valid for air cargo freight rates, too, if we look on the TAC Index (https://www.tacindex.com) while abstracting from recurrent seasonality patterns.

4. Results

4.1 Comparative analysis of transport costs and transit times

To build up a realistic and at the same challenging scenario, Shanghai in China and Hamburg in Germany were selected as the origin and destination points, as both cities have a seaport serving as a major container hub with direct connection on the China–Europe trade lane and are quite often used when it comes on freight rate benchmarking.

Table 6 summarises the transport costs and average transit times of shipping a single FCL shipment of one FEU from Shanghai to Hamburg for four modes of transport on a terminal-terminal basis for 2017 compared to figures raised by US Chamber of Commerce (2006) with sea/air calculated separately based on historical freight quotations of that time available to the authors.

By freight rate, the sea was and is still the cheapest option and air is very much higher than the other modes. Sea/air transport costs are around half of the air, whereas Eurasian rail freight is about 80% less costly than air and ranked next to the sea as the second cheapest option. In terms of transit time, which includes the actual time of transport plus time when a container is waiting at terminals or borders crossings for customs clearance or trans-loading gauge changes, etc. air (3–5 days) is by far the fastest transport solution from China to Europe, and rail (14–16 days) or sea/air (18–20 days) are about half of the time than sea (usually 30–34 days, but could be much longer when a container is subject to transshipment en route).

Furthermore, these different modes of transport come along with different routing, so that the distance of each mode travelled varies and cost per km is in line with the total transport cost of each mode. In terms of average transport speed, sea/air (about 843 km/day) is faster than rail (about 704 km/day), but due to its slower sea leg (about 627 km/day), the total transit time of sea/air is still higher than Eurasian rail freight.

Finally, most striking is a significant shift of transit times in the past decade from 45–50 days to 16 days on average with now only 1 or 2 days of variation due to different routing. At the same time, transport costs decreased from $US8,450 in 2006 to $US6,350 in 2017 for an FEU from Shanghai to Hamburg. On some specific routes from inland China cities (i.e. Chongqing or Changsha) via Kazakhstan to Germany, these transport costs can be even lower with around $US3,700 to 4,500 due to subsidies granted by provincial and local governments in China as discussed in Section 2.2.

4.2 Scenario analysis based on cargo type

In the previous section, it has been discovered that rail comes along with much shorter transit time than sea and much lower cost than air which qualifies it to be an alternative mode of transport to fit into the market niche of shipping high-value and time-sensitive goods. But goods transported by Eurasian rail freight cover a much wider range of cargo from high-

Transport mode	Year	Distance (km)	Transit time (days)	Transport cost (USD/FEU)	Cost/Distance (USD/km)	Transport speed (km/day)
Rail	2017	11,249	16	6,350	0.56	703.1
Rail	2006	–	47	8,450	–	–
Sea	2017	20,053	32	2,410	0.12	626.7
Sea	2006	–	30	2,740	–	–
Air	2017	8,822	4	32,490	3.68	2,205.5
Air	2006	–	5	25,000	–	–
Sea/Air	2017	16,008	19	16,650	1.04	842.5
Sea/Air	2006	–	19	22,600	–	–

Source(s): US Chamber of Commerce (2006), own calculations

Table 6. Transport costs and transit times for different transport modes in 2006 and 2017

value goods such as luxury products, machinery, equipment, vehicles and spare parts, and time-sensitive goods such as food and beverage, to general commodities such as textiles and chemical products as shown in Section 2.2.

Goods are considered to be time-sensitive when they are subject to depreciation and uncertain demand due to 'inventory holding costs, perishability, rapid technological obsolesce, and uncertain demand' (Hummels, 2007; Hummels and Schaur, 2013). Furthermore, inventory holding costs include the capital cost of the goods in transit, cost of buffer stock at the destination warehouse to accommodate variation in arrival time. In addition to this, depreciation costs include spoilage of perishable goods or rapid technological obsolescence. Hence, the time of goods spend in transit will impose a combination of inventory holding and depreciation costs on consumers.

Moreover, Hummels and Schaur (2013) defined the estimated value of time per day transit time which depends mainly on the value of cargo and expressed these time costs in tariff equivalents by calculating the estimated value of one day saved in transit for each product. To reflect how much consumer's value of timely delivery for the full range of product categories being traded and shipped, it was estimated that each day of goods in transit is equivalent to a tariff of about 1% per day levied on the value of cargo for most goods employing trade and shipping data from US imports of merchandise database. This estimation varies over the type of goods, as bulk products and raw materials are less time-sensitive than complex manufactures and perishable goods are subject to rapid depreciation, such as fresh fruit and vegetables (Hummels, 2007). As the daily depreciation rate of goods with high time sensitivity and high value can be as high as about 2%, one day in transit translates into a tariff equivalent of 2%.

When combining these findings with transit times and transport cost figures as shown in Table 4, estimated values of time per day in transit and value to weight ratios can now be employed for scenario analysis to include time sensitivity and value of cargo transported. Then the value of time in transit (defined as a combination of inventory holding and depreciation cost) allows assessing the relations between transport costs, transit time and total logistics costs for goods of high versus low time sensitivity between different modes of transport. Or more strictly defined:

(1) Inventory holding and depreciation costs are incorporated in the form of a tariff equivalent as a proxy. In line with the estimations of Hummels and Schaur (2013), this tariff equivalent is set to 1% per day of cargo value for goods with lower time sensitivity, and 2% per day for goods with higher time sensitivity.

(2) Calculation of total logistics costs only include the direct transport costs and indirect inventory holding and depreciation costs during the transit expressed in this tariff equivalent.

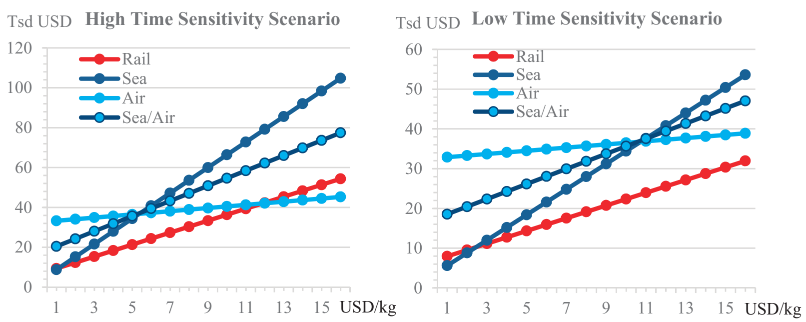
(3) An average shipment is assumed to be 10 tons per FEU, so that cargo value expressed in USD per kg can be easily calculated and compared over all four modes of transport.

Results of the scenario analysis are shown in Figure 3 and can be summarised as follows: Whenever goods shipped have a low time sensitivity, and value to weight ratio is around $US2.55/kg, rail is almost equal to sea and after around $US21.78/kg, air gets cheaper than rail. If goods shipped have a high time sensitivity, rail is already cheaper than sea for cargo values of higher than $US1.23/kg and air is then cheaper when cargo value is higher than $US10.89/kg. Hence, in both scenarios, sea is the cheapest mode of transport when cargo value is low. Then rail fits into the niche and becomes the cheaper solution for cargo values ranging from relatively low value to average and high-value goods with sea/air always coming along with higher total logistics costs.

To put these results in a better context, EUROSTAT COMEXT Dataset DS-043327 can be employed to get further insights about shipments running between China (including Hong Kong and Macao) and European Union (EU), classified according to Harmonized System (HS). In 2018, a wide range of goods was exported from China to EU with a value to weight ratio of around $US0.41/kg (HS Chapter 25–27: mineral products) to $US338.90 /kg (HS Chapter 97–99: works of art, collector pieces and antiques) and imports to EU average $US7.26/kg (see Table 7). Goods exported from EU to China came along with a value to weight ratio of $US5.65/kg on average and range from $US0.34/kg (HS Chapter 44–46: wood and articles of wood) to $US4,412.56/kg (HS Chapter 71: jewellery, etc.) in 2018.

Furthermore, it is important to note that according to applicable transport law and/or general terms of conditions, carriers on all transport modes have certain liability limits for loss or damage of goods being transported. For example, air carrier liability is limited to about max. $US31.15/kg (22 SDR/kg following to Montreal Convention of 1999 or IATA Resolution 660a effective 28 December 2019), in rail freight it is max. $US24.07/kg (17 SDR/kg according to CIM of 1999 and SMGS of 2015 with no limitation other than the value of cargo) and in sea freight usually max. $US3.54 /kg (2.5 SDR/kg in Hague-Visby Rules of 1968, see, e.g. https://www.ivt-int.org/en/basics/). This, in turn, gives a strong indication, which goods are prone to be transported by sea, air, and rail: low-value goods by sea, high-value goods by air and rail is (again) in between and value of cargo within the liability limits of the respective carriers on average (see Table 7).

Focusing on rail mode of transport only, we get a value to weight ratio of shipments between $US0.13/kg (HS Chapter 44–46: wood and articles thereof) and $US292.82/kg (HS Chapter 97–99: works of art, collector pieces and antiques) with an average of $US11.04/kg in 2018. However, 42.79% of all westbound rail traffic by weight from China to EU in 2018 is dominated by machinery and equipment with a value to weight ratio of $US14.66/kg (see Table 8). Eastbound traffic to China consists mainly of vehicles and spare parts, machinery and equipment followed by some low value, but heavyweight products (see Table 8).



Source(s): Authors' own

Figure 3. High time vs. low time sensitivity scenario

	Total	Sea	Rail	Air
Import (CIF) China to EU	7.26	4.95	11.04	80.83
Export (FOB) EU to China	5.65	2.04	13.01	117.43
Maximum carrier liability	–	3.54	24.07	31.15

Source(s): EUROSTAT COMEXT Dataset DS-043327, own calculations

Table 7. Average value to weight ratios in USD/kg by mode of transport in 2018

Table 8.
Top five of goods transported by rail between China and EU in 2018

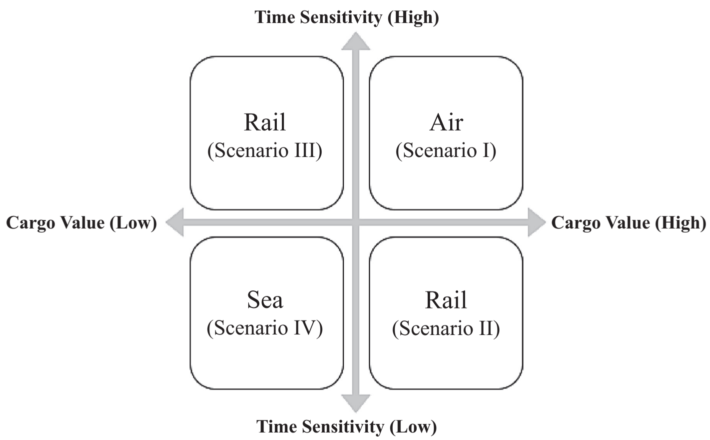
Imports (FOB) China to EU	%	$US/ kg	Exports (CIF) EU to China	%	$US/ kg
HS Chapter 84–85: Machinery and equipment	42.79	14.66	HS Chapter 86–89: Vehicles and spare parts	27.88	21.47
HS Chapter 72–83:Base metals and articles	13.79	3.19	HS Chapter 84–85: Machinery and equipment	13.83	21.08
HS Chapter 94–96:Miscellaneous manufactures	7.57	7.08	HS Chapter 44–46: Wood and articles thereof	13.67	0.13
HS Chapter 50–63:Textiles and textiles articles	6.72	9.62	HS Chapter 72–83: Base metals and articles	12.92	4.00
HS Chapter 86–89: Vehicles and spare parts	5.80	8.62	HS Chapter 47–49: Pulp of wood and articles	11.19	0.78

Source(s): EUROSTAT COMEXT Dataset DS-043327, own calculations

Cargo value is not the only way to explain the market niche of Eurasian rail freight as the modal choice depends on time sensitivity, too. Based on the above findings, the preferred modal choice from a shipper's point of view can be split in 2 × 2 scenarios (see Figure 4) as follows:

Scenario I: High-value cargo with high time sensitivity: Whenever cargo value is above $US12/kg (i.e. $US120,000 per FEU), it can be generally considered as high-valued (US Chamber of Commerce, 2006). This is especially true for equipment, spare parts, and electronic products among the goods of HS Chapter 84–89, which may require frequent weekly replenishment. In this scenario, air with the shortest transit time of less than one week and most of the time the lowest total logistics costs is the most favourable solution. However, whenever special space and weight limitations or restrictions on the transport of dangerous goods and lithium batteries occur for air, rail with less restriction on cargo type and much larger capacity available might be an alternative solution at least in some cases.

Scenario II: High-value cargo with low time sensitivity: High-value cargo with low time sensitivity can be luxury garments and leather goods. In this scenario, rail with about two weeks transit time can cover a wide range of goods from $US2.46/kg to $US21.48/kg with the lowest total logistics costs in comparison to all other modes of transport.



Source(s): Authors' own

Figure 4.
Preferred modal choice in different scenarios

Scenario III: Low-value cargo with high time sensitivity: When the average cargo value is around $US6/kg (i.e. $US60,000 per FEU) or less, this can be considered as low-value cargo. In this scenario, for goods with short lead-time demand (e.g. high-fashion apparel, electronic products), rail continues to be the favourable option with half of the transit time than sea and much lower transport cost and larger capacity than air. Rail is able to provide the cheapest total logistics cost for a range from $US1.23/kg to $US10.89/kg.

Scenario IV: Low-value cargo with low time sensitivity: For the majority share of transport goods with low-value of less than $US2.46/kg, sea with by the far largest shipping capacity available is the cheapest solution closely followed by rail.

5. Conclusions

This study examined the service quality of Eurasian rail freight based on transit times and transport costs, and scenario analysis with a special focus on cargo type and associated total logistics costs have been used to identify its market niche from a shipper's point of view. Taking the transport of an FEU from Shanghai to Hamburg as an example, we found that present Eurasian rail freight service fits into the sweet spot between sea and air. Eurasian rail freight is about 80% cheaper than air with only half of the transit time of conventional sea. Our scenario analysis further suggests that when shipping time-sensitive goods with cargo values ranging from $US1.23/kg to $US10.78/kg, rail is cheaper than all other modes of transport and much faster than sea – the same is valid for goods with lower time sensitivity ranging from $US2.46/kg to $US21.78/kg.

5.1 Managerial implications

Moreover, some practical recommendations on the way forward for Eurasian rail freight service development in the Belt and Road era should be noted. On a strategic level, high-level collaborations among the government of countries and railway stakeholders along the Belt of BRI are required to foster favourable legal and technical agreements to facilitating Eurasian rail freight operations. On an operational level, keep rail freight rates low to maintain competitiveness, optimise routing to lower transit times, target market to seize profit, improve public awareness to gain business are recommended for Eurasian rail freight operators to keep developing in this new Belt and Road era.

BRI is considered as a major enabler to the rapid development of Eurasian rail freight within the last decade and it can be regarded favourable in several ways.

5.1.1 Faster than sea and cheaper than air. In Section 4.1**,** a general comparison based on the costs and transit times among rail, sea, air and sea/air was conducted, which pointed out that Eurasian rail freight is about 80% cheaper than air with only half of the transit time of sea. Besides, a historical shift of its positioning in the market has also been captured – its transit time has significantly shortened from one month (or more) to only two weeks or even less. The driving force behind this significant improvement of its service in recent years can be traced back to two main factors. On one hand, BRI focuses on the Central Corridor rather than the traditional Northern Corridor, which helps to boost the domestic economy in the rural western part of China, as well as avoids dealing with Russian monopoly on the TSR. Therefore, new railway infrastructure projects and dedicated container block train services launched under BRI have greatly revived Eurasian rail freight. On the other hand, changes to global trading patterns and increasing demand for the speed to market also drive the development of intermodal logistics solutions both within Europe and along the New Silk Road (Davies, 2017).

5.1.2 Alternative to air for time-sensitive goods. Certainly, a pure transport cost comparison is not sufficient, as other costs occur during the transport process like inventory-holding and depreciation costs are worth taking into consideration. Therefore, in Section 4.2, they have been incorporated to compare the total logistics costs of rail, sea, air as well as sea/air where rail stands out as the most favourable transport solution when it comes on time-sensitive goods with a cargo value ranging from $US1.23/kg to $US10.89/kg. In the past, air used to be the only option when shipping high-value, time-sensitive goods. But as transit time shortened and transport service got more reliable, rail becomes a perfect alternative for time-sensitive goods, especially for those with average cargo value not necessarily worth to be transported by air. Besides, rail freight with higher capacity than air can accommodate almost all kinds of containerised cargo, which again demonstrates higher service availability.

5.1.3 Alternative to sea for low-value goods. Again, our scenario analysis found that when shipping goods with low time sensitivity, rail would be the cheapest option for cargo ranging from $US2.46/kg to $US21.78/kg. Sea used to be the best option for low-value goods. However, present short-term flexibility tactics executed by liner shipping companies like slow steaming and re-routing of the vessel as well as blanking of sailings results in longer and less reliable transit times (Munim and Schramm, 2017; Finnsgård *et al.*, 2018) and this cannot fulfil the requirement for today's agile supply chains. In this case, rail with a speed advantage over sea can also cover a wide range of goods from low to high value. Instead of upgrading from sea to air (or sea/air), rail gives the customer a window of opportunity to meet deadlines without bearing the full expense of air.

Since the global economy continues to slow down, the world searches for new engines to drive trade growth, the BRI offers 'a major development framework and opportunity for connectivity, international trade and economic development' (Davies, 2017). The momentum of Eurasian rail freight has already been witness to enhance connectivity and trade growth between China and Europe. Implications of this on supply chains can be summarised in the subsequent sections.

5.1.4 Not competition, but another option. Our calculations in Section 4.1 demonstrate that Eurasian rail freight service is an emerging competitive solution – faster than sea and significantly cheaper than air. However, rather than being seen as a threat, it provides a potential alternative for companies that no longer like to consider air (or sea/air) as the only option when shipping high-value and/or more time-sensitive goods. This offers a cost-efficient option to tailor freight lead time relevant to production.

5.1.5 The value of short transit time. Matear and Gray (1993) suggested that when shipper and freight forwarders deciding on freight service choice, transit time is frequently considered as more important than a low freight rate. As shown in Section 4.2, a substantial amount of inventory holding and depreciation costs will add up to the total logistics costs during transport if the transit time of a shipment is too long. This is especially critical for perishable or time-sensitive goods with frequent changes in consumer preferences (US Chamber of Commerce, 2006). Eurasian rail freight with shorter transit time than conventional sea and higher reliability can help shippers to reduce total logistics costs and gain more flexibility on cash flow and liquidity.

5.1.6 Bring agility to supply chains. Shorter and more reliable transit times give Eurasian rail freight advantage of higher accountability. On one hand, this will allow companies to have more control over their logistics operation and production forecasting; on the other hand, it will encourage companies to conduct 'just-in-time' business practices with timely delivery to reduce production costs by minimising inventory (US Chamber of Commerce, 2006). Besides, with more frequent scheduled container block trains and adding more terminals of origin and destination, the Eurasian rail freight service can offer a variety of end-to-end routing options, which again gives shippers more flexibility than sea and air. Moreover, high reliability of service delivery and flexibility of service availability will bring agility to the company's supply chains, which potentially offer companies a chance to tailor-made their supply chains based on different product categories.

5.2 Research limitations and future research directions

Reflecting research process and findings, some limitations have to be remarked. Firstly, this paper intends to examine the service quality of Eurasian rail freight and compares it with other modes of transport. By doing this, firstly it focused on two quantifiable attributes – transport costs and transit time. Of course, other important attributes contribute to service quality as well, such as transit time reliability, service availability and environmental impact, which are much harder to quantify.

Secondly, given that the Eurasian rail freight market is still in its infancy state (Sárvári and Szeidovitz, 2016), rail freight quotes collected by the authors may not fully reflect long-term competitive freight rates that companies get in the markets, as freight quotes obtained, e.g. from freight forwarders might be already being bundled with other value-adding services on top of bare costs of rail transport. Moreover, Eurasian rail freight operations under BRI are still heavily subsidised as discussed in Section 2.2, which may to some degree hide real costs of transport service provision. Besides this, the costs of local cartage service at both origin and destination as well as other ancillary costs were not included in our calculations.

In sum, this study does not intend to provide a price list for individual business decisions, however, it does offer guidance for assessing transport options available for shippers. Last but not least, much larger data samples, specific cost models and detailed market inquiry are required to get the full picture.

Accordingly, further research should investigate traffic volume on the different rail routes as shown in Section 2.1 to capture the Eurasian rail freight market landscape, thus identifying market demand for rail and providing recommendations for further route optimisation. However, present scarcity and opaqueness of statistics available to the public make it almost impossible to determine the impact of BRI to the full extent (Bucsky, 2019).

Another direction would be to collect more detailed data of freight costs and transit time which enables to compare total logistics cost of shipping goods from specific origins to destinations by rail, sea, air, and sea/air respectively.

Finally, some other key attributes of service quality briefly outlined in Section 3.1 such as transit time reliability or service availability not explicitly included here in our analysis could be assessed. However, to raise representative data in this respect needs a tight collaboration by major market players engaged in Eurasian container block train operations alike the Clean Cargo Working Group (https://www.clean-cargo.org/) in liner shipping as yet, no public data like detailed train schedules or geolocations of block trains is available at all.

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Appendix

Author	Transport mode studied	Route scenario	Modal choice considerations	Cargo attributes
Rodemann and Templar (2014)	Rail, sea, road	Hamburg – Beijing Duisburg – Lanzhou	Freight rate per FEU, transit time, general enablers and inhibitors	General high vs. low-value cargo
Besharati *et al.* (2017)	Rail, sea	Different block train origin-destinations	Freight rate per FEU, government subsidies	Export goods from EU that benefit from rail
Chen *et al.* (2017)	Rail, sea	Hefei – Hamburg	Freight rate per FEU, transit time, general mode characteristics	N/A
Seo *et al.* (2017)	Rail, sea, air	Chongqing – Rotterdam	Freight rate per FEU, transit time, and transit time reliability	Laptops as high-value good object of case study
Yang *et al.* (2018a, b)	Rail, sea, sea/rail via Piraeus	China–Central and Eastern Europe	Freight rate per FEU, trip time and frequency	Cargo value, time sensitivity, fragility
Wiegmans and Janic (2019)	Rail, sea	Shanghai – Rotterdam	Operational, economic, environmental and social performance	N/A
Jiang *et al.* (2018)	Rail, sea	China – EU, different origin-destinations	Total freight costs per FEU, government subsidy, transit time	Scenarios of IT products vs. products of other shippers
Jiang *et al.* (2019)	Rail, sea	Chongqing/ Shanghai – Hamburg	Freight rate per FEU, transit time	N/A
Wen *et al.* (2019)	Rail, sea	Nanjing/ Shanghai – Hamburg	Costs, transit time, reliability, security, environmental. impact	N/A
Bucsky (2019)	Rail, sea	China –EU	Freight rate per TEU, transit time	Value and weight per product group
Dunmore *et al.* (2019)	Rail, sea, air	China – EU	Transport price per unit, transport time	General high vs. low-value cargo
Lu *et al.* (2019)	Rail, sea	Beijing/Tianjin – Berlin/Rotterdam	Location of origin-destination, freight costs, time costs	Cargo value included in time cost considerations
Kundu and Sheu (2019)	Rail, sea	China–Germany/ Hamburg	Freight rate per FEU, government subsidy, transit time, and mode reliability	High- vs low-value shippers with different preset service level preferences
Feng *et al.* (2020)	Rail, sea, air	Wuhan–Hamburg	Operating costs and freight rate per FEU, government subsidy, transport time	N/A
Song *et al.* (2011)	Sea/rail, sea	Korea/Japan/ China – EU, different routes	Freight rate per FEU, transit time	N/A
Song and Na (2012)	Sea/rail, sea	Korea/Japan/ China – EU, different routes	Freight rate per FEU, transit time	N/A

Table A1.
Comparative research on Eurasian rail freight

(*continued*)

Author	Transport mode studied	Route scenario	Modal choice considerations	Cargo attributes
Tsuji (2013)	Sea/rail, sea	Busan – Moscow via different routes	Freight rate per FEU or TEU, transit time	N/A
Kim *et al.* (2020)	Sea/rail, sea	Korea – EU via TSR	Diverse set of strengths, weaknesses threats and opportunities	N/A
Moon *et al.* (2015)	Rail, sea/rail, sea (NSR, SCR)	Korea – EU via TSR	Transport distance, time, costs, service, safety, route and mode awareness	N/A
Zeng *et al.* (2020)	Rail, sea (NSR, SCR)	Shanghai/ Shenzhen/Dalian – Hamburg	Freight rate per FEU, transit time, safety, convenience, frequency	Value of shipper preference

Source(s): Authors' own

Table A1.

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