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Belt and road: more competition between sea and rail? A generalized cost approach

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Abstract

Eurasiatic rail freight transport has experienced a dramatic growth during the past years. Since 2011, rail traffic between China and Europe experienced a spectacular growth as the transport volumes increased from 25,000 TEU in 2014 to 175,000 TEU in 2017.

The main research question of this paper is what the future will bring for rail compared to the other modes on the China – Europe connection. More specifically, to what extent will rail become a real competitor? In this research a combination is made between literature search, scenario development and cost modelling.

The Belt and Road policy initiative as a main driver is the starting point for the specification of the corridors and the scenarios to be considered. Equally, the barriers on the Belt and Road path are identified. With that information, a number of scenarios of future rail development on the connection were derived, which were the basis for the calculation of the route generalized costs. Next to that also three different sensitivity analysis are preformed to research the impact of some inputs used in the cost modeling. Based on these calculations conclusions are drawn with respect to the possible competitive advantage of the rail land bridge compared to the maritime route.

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Keywords: Belt and Road, generelied cost modeling, maritime transport.

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1. Introduction

Eurasiatic rail freight transport has experienced a dramatic growth during the past years. 10 years ago, there was no frequent rail connection yet between China and the European continent. A negligible amount of goods was transported by rail between China and Europe via the Trans-Siberian Railway Link. The connection featured high transit times and a lack of reliability. The US Chamber of Commerce in 2006 summarized the situation as follows: “The current land transport connections between Asia and Europe do exist, but they have no viable share of the commercial market”

Western companies, end of the 2000 decade, gradually started experimenting with direct Eurasian rail freight connections. DB Schenker launched a weekly link between Shanghai and Duisburg in 2009. Because of increasing wage costs in the Chinese coastal provinces, Hewlett-Packard (HP) decided to move its production facilities inland, to Chongqing in particular. This move of course had a substantial impact on the HP supply chain, since goods could now reach Europe over land within 25 days, instead of 37 days via sea. Hence, HP started researching the feasibility of a direct, frequent rail connection between Chongqing and the European continent. As part of its ‘Go West’ strategy, the Chinese government supported this initiative, but the co-ordination with policymakers of other concerned countries turned out to be less evident.

The launch of the Eurasiatic Economic Union in 2011 was a turning point. That implied that transit countries Kazakhstan, Russia and Belarus became a customs union. HP’s pilot phase ended successfully end of 2011 and became a weekly rail freight connection between Chongqing and Duisburg a year later. This service was a block train, in other words a train going directly to its final destination and reserved by one sole customer.

Today, there are three main corridors between China and Europe (Figure 1). The Northern corridor connects to the Trans-Siberian rail line from either Mongolia or Manchuria. The middle corridor has several variants, but these all cross Kazakhstan. Finally, there is a strong will in Central Asia and Caucasus to develop a southern corridor. The latter is also called the Trans-Caspian Corridor, and could be a potential route for European food producers to avoid the Russian sanctions. Nevertheless, there are no frequent connections yet between China and Europe on this southern route. This is mainly due to the poor state of the infrastructure on that connection. The majority of the Eurasian rail flows,71% in 2018, passes by the middle corridor, up from only 12% in 2011 (Vinokurov et al., 2018; Kenderdine, 2018). The latter implies that the northern route has lost importance.

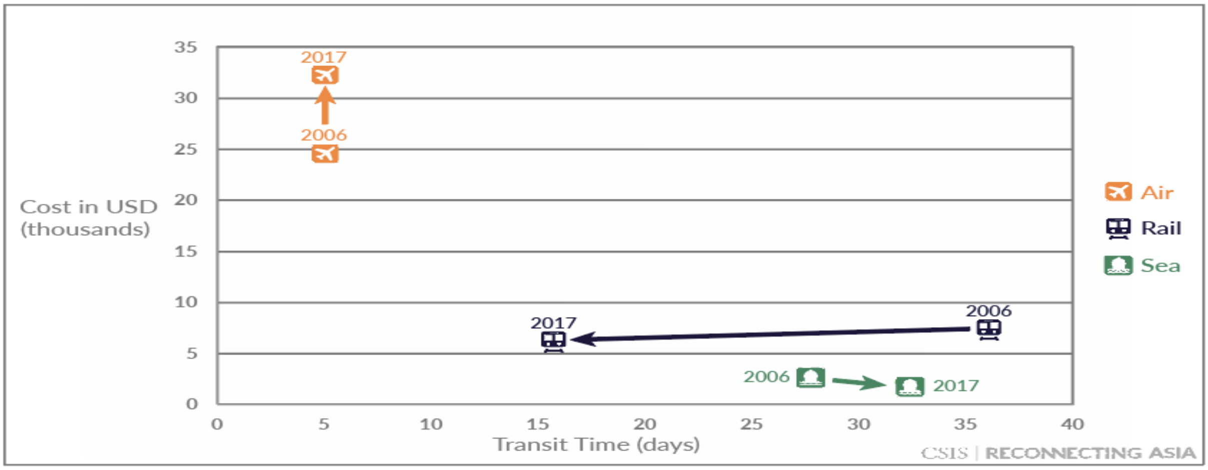
Figure 1: The three main Asia – China rail corridors

Source: Hillman (2018)

Overall, since 2011, rail traffic between China and Europe experienced a spectacular growth. Volumes increased from 25,000 TEU in 2014 to 175,000 TEU in 2017. Figure 1 shows the main points of origin / destination on the considered routes. In China, larger hubs are located rather inland, mainly due to the competition with maritime transport in the coastal provinces.

Figure 2 shows that the competitive position on the China – Europe corridor of rail versus air and sea in terms of transit times and costs has improved over the 2006-2017 period. Rail featured a significant drop in transit time, while also the average price charged to users declined slightly. Sea transport also featured a drop in prices charged, but its transit time went up, mainly due to slow steaming. Air transport is clearly the fastest with no change in the transit time but with an increase of its rates. Hence, rail is the only mode which over the considered period managed to improve both its transit time and cost.

Figure 2: Evolution of transit times and costs of the various transport modes connecting China to Europe over the period 2006-2017



Source: Hillman (2018)

The question is what the future will bring for rail compared to the other modes on the China – Europe connection: to what extent will rail become a real competitor? This paper deals with that topic. It does so by combining literature search, scenario development and cost modelling. For the latter there is a challenge in terms of data availability for a number of countries along the above-mentioned corridors, especially those east of Europe.

Section 2 looks at the investment plans that are on the table for rail, as part of the broader geo-political strategies. Section 3 addresses the challenges and risks related to elements of those plans. Based on that combined information, section 4 develops a number of scenarios of future rail development on the corridor. Section 5 presents the modelling methodology for the calculation of the total chain costs. Section 6 applies this methodology to calculate and compare the total cost for the different transport alternatives for the selected connections.. Finally, section 7 wraps up the findings in a conclusion.

2. Rail policies and plans on the China – Europe corridor

The sudden growth of the Eurasiatic rail freight connections can be attributed to a number of political, economic and technical factors. There is a general consensus though that this transport mode could not have developed as quickly, if China’s political and financial support would not have been as extensive as it was.

Chinese president Xi Jinping pronounced himself in fall 2013 in favour of economic integration on the Eurasiatic continent. In Kazakhstan, he plead for launching the ‘Silk Road Economic Belt’. One month later, he plead for

setting up a regional co-operation body, called 'The Maritime Silk Road'. Together, these were the main components of the Chinese 'One Belt One Road' (OBOR) initiative. (Wuthnow, 2017)
The president's foreign policy is not totally disruptive though, but continues along the foreign infrastructure development lines of the past 25 years. These had been set up in Central and South-East Asia and concerned the energy and transport sector. Several of these projects have in the meantime been put under the OBOR framework, like the Chongqinq-Duisburg rail connection, or the Bangladesh-China-India-Myanmar economic corridor, started up in 1996. (Wuthnow, 2017)

China was not the only player in the Eurasiatic development area. Since 1992, the European Union has launched a number of projects that are part of the 'Transport Corridor Europe-Caucasus-Asia' (TRACECA) framework. Furthermore in 2011, the at that time American Minister of Foreign Affairs Hillary Clinton announced the 'New Silk Road Initiative', that would integrate Afghanistan better with the other Central-Asiatic economies. Korean president Park Geun-hye announced in 2013 that his country was about to launch a 'Eurasia initiative' to improve regional connectivity. The fact that Belarus, Russia and Kazakhstan became a customs union implies that only three customs zones need to be passed between China and Europe.

What makes OBOR different from the preceding initiatives, is its geographical size and scale. The framework foresees six economic corridors that are to connect China to its neighbouring countries. Table 1 provides an overview of the corridors and the most prominent projects. Moreover, OBOR would mainly be financed through multilateral development banks on the one hand, and Chinese state banks and dedicated funds (for instance the Silk Road Fund) on the other (Lau, et al 2017; Wuthnow, 2017). Nevertheless, synergies were sought with other continent's initiatives, for instance the European Juncker investment plan. To that purpose, the Sino-European Connectivity Platform was launched, where Trans-European Transport Network funding allows matching (van der Putten et al 2016). Similarly, the Kazakh government saw Belt and Road as an opportunity to develop itself as a logistics hub in the region, especially after the 2014 Russian crisis and dropping oil prices, which both hit hard for Kazakhstan. The Kazakh 'Nurly Zhol' plan not only foresees large infrastructure works, valued at 9 billion USD, but also the development of ten free trade zones, so as to better accommodate transit traffic (Kenderdine, 2018).

Table 1: OBOR corridors, partners and main projects

Corridor	Partners	Main projects
Bangladesh-China-India-Myanmar	Bangladesh, India, Myanmar	• Padma bridge (Bangladesh) • China-Myanmar LNG pipeline
China-Central-Asia-West-Asia	Iran, Kazakhstan, Kyrgyzstan, Kuwait, Qatar, Saudi-Arabia, Tajikistan, Turkey and Uzbekistan	• Renewal Manas airport (Kyrgyzstan) • High speed rail network Turkey
China-Indochina	Cambodia, Vietnam, Thailand, Laos	• China-Laos rail connection • Lancang-Mekong shipping route
China-Pakistan	Pakistan	• Karakorum motorway • Gwadar port
China-Mongolia-Russia	Mongolia, Russia	• Altai LNG pipeline • Altanbulag-Ulaanbaatar motorway
Eurasiatic Land Bridge	Belarus, Bulgaria, Czechia, Greece, Hungary, Kazakhstan, Poland, Russia, Serbia and Slovakia	• China-Europe rail freight transport • Piraeus port

Source: Lau, et al (2017), Wuthnow (2017)

China also financially heavily supports users that apply Eurasiatic connections. Hillman (2018), Forbes (2018) and Vinokurov et. al, (2018) indicate that per container, subsidies of between USD 1,000 and USD 5,000 apply. Between 2011 and 2016, about USD 300 million of subsidies was awarded. That amount is relatively limited in

comparison to the USD 113 billion the country will invest in rail infrastructure in 2018 only.
The future success of this OBOR policy is highly determined by the strength of its motivation. It appears that stakes for China are high, both from a geo-political as well as a geo-economic perspective.

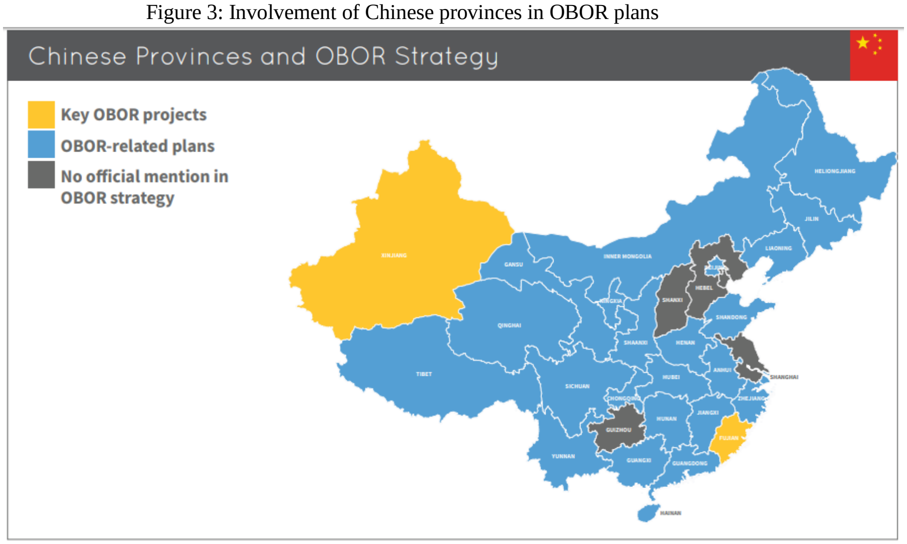
Geopolitics in this case encompasses three sub-motives: favouring regional stability, safeguarding China's energy imports, and increasing the Chinese sphere of influence on the Eurasiatic continent. (Cai, 2017)

With respect to regional stability, OBOR is to create a more stable political climate in the Western as well as Southern Chinese periphery. President Xi Jinping aspires for Eurasia to evolve towards a 'community of shared interests'. This concerns in the first place its own western Province of Xinjiang. Economic development there should reduce revolting sentiments among the local, mainly Uighur, population. Furthermore, it also concerns other countries, especially India and in South-Asia, where common OBOR interests might take away territorial disputes. (Wuthnow, 2017)

Energy ensurance has been a topic of increasing strategic importance for China, as its dependence on particularly oil and gas increased seriously in line with economic growth. In 2014, China has become the world's largest energy importer. At the same time, about 80% of China's energy imports passes through the Malacca Strait, which makes these flows very vulnerable to blockings. (Cai, 2017; Engdahl, 2017)
The third and last geopolitical issue concerns the balance to be struck between the Chinese desire to increase its sphere of influence on the one hand, and the US 'China Containment Policy' on the other. A possible equilibrium then is a focus on its Western periphery, where US interests are more limited. (Wuthnow, 2017; Stratfor, 2018)
On the geo-economic side, again three sub-motives for OBOR success are mentioned: regional-economic development, overcoming its own middle-income trap, and accommodating overcapacity in its production system. (Cai, 2017)

As to regional-economic development, the growing inequality between interior, western-Chinese regions and its coastal area is a source of increasing concern. For example, Shanghai's GDP is about five times as high as that of the western Gansu province. Despite the Chinese 'Western Development Strategy', the share of the western provinces in Chinese GDP has increased only from 17.1% in 2000 to 18.7% in 2016. The result of this lasting public financial support is that the four western provinces (Xinjiang, Tibet, Qinghai and Gansu) score the lowest on the China Economic Research Institute's Free Market Index, featuring lots of state-owned enterprises. To remedy this failing policy, the Chinese government has decided to shift away from putting public money into the provinces directly, to connecting them through OBOR. The connections do not target only the western provinces: a large part of China is implied in OBOR-related initiatives, as shown in Figure 3. (Cai, 2017)

Figure 3: Involvement of Chinese provinces in OBOR plans



Source: Cai (2017)

China's middle income trap is a second sub-motive for investment in OBOR. Through increasing wages and land rents, China has lost part of its comparative advantages against other production countries in the world. Its government therefore wants to reinforce its focus on 'high end' products, which it hopes that OBOR can contribute to in making those products attractive to buyers along OBOR corridors. (Cai, 2017; Hsu, 2017)

Third and finally, as a reaction to the financial-economic crisis, the Chinese government had heavily stimulated the production of steel, cement and aluminium. China's steel production capacity for instance rose from 512 million tonnes in 2008 to 803 million tonnes in 2015. This increase alone is bigger than the total production of the US and the EU together in 2015. However, at the same time, interior and foreign demand started to drop. The Chinese government therefore hoped that the production of lower-value goods could be pushed to neighbouring countries, with OBOR connections enabling access to these production locations. At the same time, China would focus on higher-value goods production, with OBOR allowing for access to markets. However, it is questionable whether the real cause of the overcapacity is there, or rather the global fall in demand due to a slowing economy. (Cai, 2017) Next to the stimulators of the Belt and Road policy, as reviewed in this section, there are also a number of potential obstacles. They will be introduced in the next section.

3. Challenges and risks in Chinese Belt and Road rail policy

The Chinese government, in its implementation of the Belt and Road policy, encounters a number of obstacles. They can be summarized as mistrust against China, instable governments in neighbouring countries and big project risks. (Cai, 2017) First of all, there is significant mistrust among the countries participating in Belt and Road. The Indian government for instance is sceptical about Belt and Road due to the historical animosity between the countries, and the fact that the rail connection runs through the disputed areas of Jammu and Kashmir (Cai, 2017). Moreover, out of discontent with the existing financial institutes, dominated by the US and Japan, China had decided to set up the 'Asian Infrastructure Investment Bank'. This multilateral development bank features 64 members, all situated along the Belt and Road axes. The bank is heavily dominated by China, which again leads to suspicion among the other bank members. (Garcia-Herrero, 2017; Shambaugh, 2016)

Furthermore, a number of the countries involved in Belt and Road suffer from government instability. In some of the key countries, terrorist insurgency from separatist or religiously-extremist groups creates troublesome development situations. (Raza, 2017)

Third, risks related to projects of this scale are first of all of financial nature. The increasing Chinese debt does worsen this status. The IMF showed itself particularly worried about the Chinese situation: "the Chinese credit-to-GDP ratio is 25% above the long-term trend, while corporate debt has reached 165% of GDP and household debt is increasingly linked to asset-price speculation. The buildup of credit in traditional sectors has gone hand-in-hand with a slowdown of productivity growth and pressures on asset quality" (the Guardian, 2017). The debt status may be worsened itself by the 'white elephant' character of a number of the Belt and Road projects. Moreover, moral hazard may be at play: some countries may be interested in using the Chinese financing, not having the intention to actually pay back. Chinese financiers also seem less inclined to develop favourable conditions for Belt and Road projects. (Cai, 2017).

4. Scenarios for future development

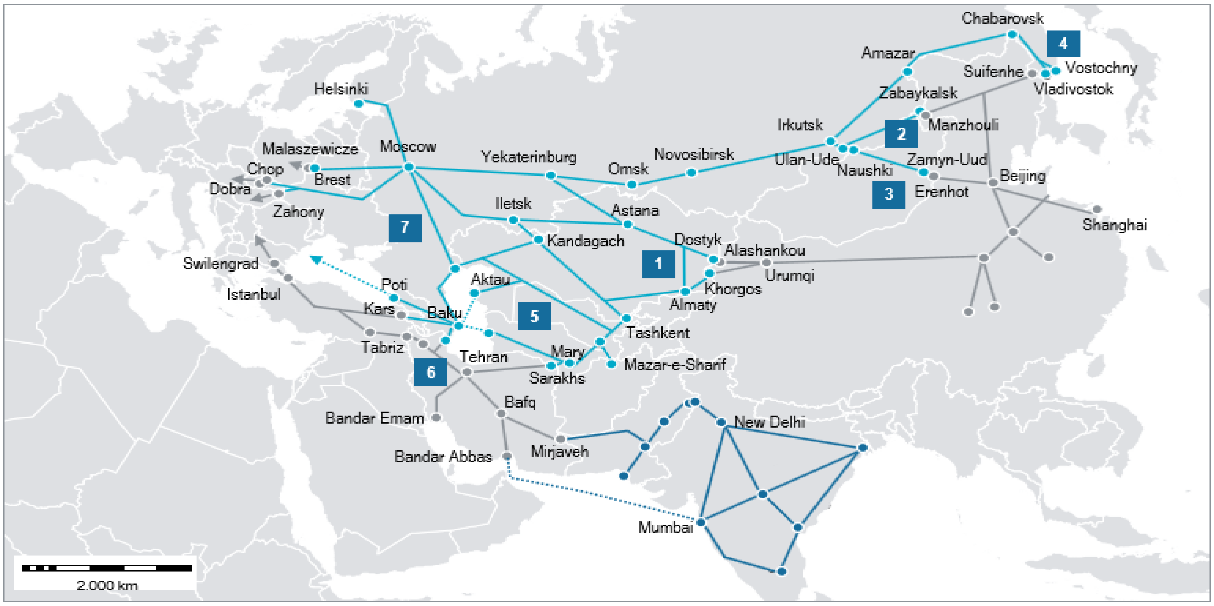
For the future development of Belt and Road routes, and to determine the relevant applications and scenarios to analyse in this paper, a comparison is made in Table 2 of the various sections and their potential and barriers. The section numbers are mapped in Figure 4.

It are the border crossings on the various routes that make transit times increase, especially on the Southern route. For instance, it takes 17 to 20 days to transport a container by rail from Chengdu to Istanbul, whereas one needs only 12 to 15 days from Chengdu to Duisburg. A supplementary barrier on that route is the Caspian Sea, which imposes intermodal transport partly by water, which further increases transit time and cost. For instance, there is only one weekly container feeder service between the Azeri port of Alyat and the Kazakh port of Aktau. Its transit time is about 36 hours. Furthermore, handling time of one loaded train in both ports is estimated at 24 hours. (Berger, 2017; Trans-Caspian International Trade Route {TITR} , 2018)

Table 2: Belt and Road sections and their potential and barriers

Route	Capacity and characteristics
1) Via Alashankou/Khorgos	• Good infrastructure • High reliability • Sufficient capacity
2) Via Manzhouli/Zabaykalsk	• Good infrastructure • High reliability • Limited capacity Zabaykalsk
3) Via Erenhot (Mongolia)	• Alternative for route 2, with additional border crossing • Limited infrastructure Mongolia
4) Via Vostochny (Russia)	• Good infrastructure • High reliability • Suitable for traffic from South-Korea and Japan
5) Via Dostyk/Khorgos & Baku	• Alternative for South-European destinations • Caspian Sea needed (intermodal)
6) Via Khorgos/Tashkent/Tehran	• Lacking infrastructure • Political instability
7) Via Tehran & Baku & Moscow	• North-South route (India-Europe traffic) • Under construction

Figure 4: Belt and Road sections and their border crossing points



One also has to mention that Chinese policymakers show an interest in creating a ‘Land-Sea Express Route’. This route contains both a longer-run maritime and land component, as goods are first transported by ship to the Greek port of Piraeus, to continue their voyage to Central or Western Europe by rail. This route would reduce the classical maritime route between China and mainland Europe by about 4,500km, making the transit time shrink by between 8 and 12 days.

However, to date, hinterland connections from Piraeus are still limited to two corridors: Corridor IV, along Bulgaria and Romania, and Corridor X, along Serbia and Macedonia[†]. Corridor IV consists of single track and allows for speeds of 60 or 70kms/h. Transit time from Thessaloniki to Budapest therefore is 26 hours. Corridor X is 300kms shorter, but features even stronger speed limitations due to lacking capacity, resulting in a transit time between Thessaloniki and Budapest of 49 hours. Nevertheless, due to the increasing activities by Chinese COSCO in the port of Piraeus during the past years, the development of the concerned corridors was heavily stimulated. COSCO started operating block train services direction of Central Europe. These services aim at multinationals that have a distribution centre at the port, including HP, Sony, Foxconn, Hyundai and Huawei. Since end of 2017, eight freight trains a week operate the service. Corridor IV is also among the TEN-T core projects, which implies that priority European funding is dedicated to the project.

The path towards improving the rail connections is not always smooth though. For corridor X, the Serbian government wanted to collaborate with Russian Railways (RZD) and China Railway Group Limited (CREC). However, the European Commission intervened, as this was not according the European granting rules. Further on, some European officials see the growing Chinese involvement in Central and Eastern Europe as a threat and part of a Chinese ‘divide and rule strategy.
For the above reasons, the choice is made to include five different routes between Asia and Europe in the analysis of this paper:

- The classical maritime route with call at the port in the Hamburg – Le Havre range
- The middle rail connection n°1 via Kazakhstan (Khorgos)
- The northern rail connection n°2 via Russia (Manzhouli)
- The land-sea route via Koper
- The land-sea route via Gdansk

For the maritime routes, the last-mile land part in Europe is assumed to be performed by road for the ports of Gdansk and Koper, while for Rotterdam all three hinterland modes (road, rail and inland waterways) are considered. In China, all three possible land modes (road, rail and inland waterways) are considered if available.
Per transport chain[‡] the most suitable routes will be selected and compared.

5. Chain cost modelling methodology

To compare the five routes, a model is applied that allows calculating the total generalized chain cost. This model was in a first version developed in van Hassel et al. (2014). In this model, the total supply chain, including maritime transport, the port process and hinterland transport is taken into account. The main reason to lay the emphasis on the supply chain is that container liners, seaports and land transport modes will compete along these supply chains. This is illustrated in Figure 5, where the chain with the lowest overall generalized cost will be the most attractive chain.

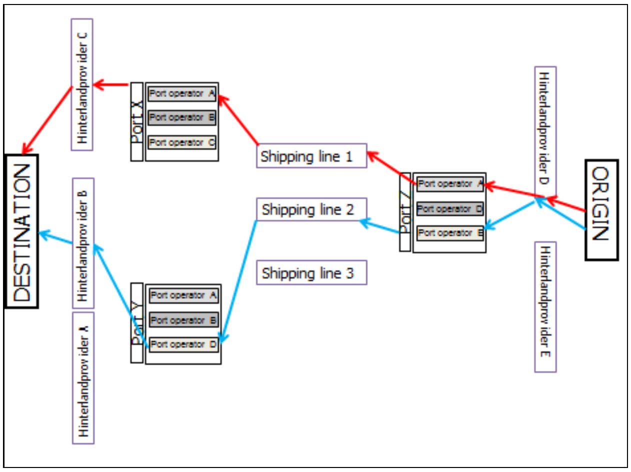
In order to calculate the chain cost, first the successive ports in a container loop have to be defined. This loop will determine the maritime part of the chain. and encompasses the maritime leg of the supply chain.
In the model, different aggregated hinterlands are connected via a route with the relevant ports (bold lines in Figure 6). The aggregated hinterlands are defined as a summation of different smaller geographical areas, which in Europe correspond to NUTS-2 areas. Each aggregated hinterland is served by at least one and usually by several ports. Each port is built up of a set of terminals, all of which have their own set of characteristics. From each port terminal, the hinterland connections via road, rail and inland waterways (if applicable) to all the disaggregated hinterland regions are incorporated into the model.

From each terminal in a port, the distances towards the hinterland via road, rail and inland waterways (if available) are incorporated in the model. This allows to calculate the cost per mode from a terminal to a hinterland destination.

[†] More information on these corridors can be found at the World Bank: http://projects.worldbank.org/P108005/corridor-x-highway-project?lang=en .
[‡] A transport chain has an origin in Asia (province level) and a destination in Europe (NUTS-2 level) or vice versa.

A chain is defined as a route from an area in a specific aggregated hinterland to an area in another aggregated hinterland. A chain therefore has a beginning and an end. In order to calculate the chain cost from a point of origin to a point of destination, the model not only calculates the total cost of the ship, but it also incorporates the cost of transporting a container from a hinterland area to a port on both ends of the chain, the cost of a container in the port phase (port dues, pilotage, container handling, etc.) on both chain sides, and the cost of transporting via sea the container from the port of loading to a port of unloading.

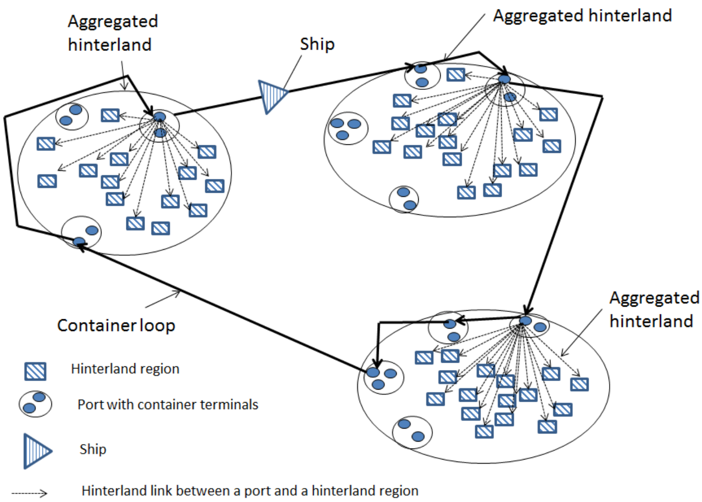
Figure 5: Supply chain view on port competition



Source: Meersman and Van de Voorde (2012)

The model by van Hassel et al (2014) allows calculating the generalized chain cost from a selected point of origin, via a predefined container loop to a destination point§. Figure 6 gives the general overview of the developed model.

Figure 6: Structure of the chain cost model



Source: Van Hassel et al (2018)

§ The model was coded in C# and uses Microsoft Excel (data) and JMP11 (maps) as output formats.

The hinterland model can be used to calculate the hinterland transport cost from the selected container terminals in the selected ports in Europe, the US and China. The generalized costs of three different transportation options (road, rail and inland waterways) are calculated. Therefore, with this model it is also possible to calculate the cost of purely land-based flows using for instance rail.

An important element of the generalized cost is the transport time. The transport time for the entire transport chain is therefore incorporated in the model. This means that the transport time from a hinterland region (including a dwell time at an inland terminal for rail or inland waterway transport) to a port, the dwell time of a container at a deep-sea port, the maritime transport and the port and land transport times at the destination hinterland are taken into account. The model version developed for this paper, builds on the version of van Hassel et al. (2016), and includes extensions and more detail in particular for the cost structures, elements and values applicable to the non-European countries on the considered rail link between China and Europe. First of all, the Russian situation is introduced with more detail. Russian authorities use two different methodologies to calculate the rail tariffs for rail transporters: one for transit traffic, and one for none-transit traffic. In this paper, obviously, we are interested in transit traffic, given the China-Europe focus. The tariffs for transit traffic are set according to the 'International Railway Tariff' guidelines. A number of parameters apply: nature of the commodities, number of used carriages, own or leased carriage, etc. The tariff is composed of three main components: infrastructure usage charges, traction charges and use of leased freight wagons (if applicable). Hence, in case of own operations, one should deduct from the tariff the applicable wagon rental charges.

In van Hassel et al (2018), the first complete chain cost calculations were made for transport between the US and Europe. These calculations include the hinterland transport on both sides of the chain both in the US and in Europe. In this paper, the same approach is used but now also the Chinese hinterland is incorporated in a similar way. For the development of the road transport cost in China the work of Wang et al. (2011) is used.

The cost function to determine the generalized road hinterland cost, for product type i, in China is:

$$C_{R,i}^{CN} = (C_{Driver} + C^{FIXED}) * TT_{Road} + (C_{Toll} + C_{Fuel}) * D_{Road} + C_i^{Cargo} * TT_{Road} \quad (1)$$

In which C_{Driver} is the cost of the driver of a truck ($/h), C^{FIXED} is the fixed cost per hour ($/h), TT_{Road} is the transport time for road transport in China (h), C_{Toll} is the toll cost per km, C_{Fuel} is the fuel cost per km and C_i^{Cargo} is the cargo dependent value of time.

The data used for the Chinese road hinterland cost are taken from German Chamber of Commerce in China (2017). An additional element with respect to the road cost in China is that there are no mandatory driver resting times. Therefore, in the cost calculations, it is assumed that in China only two drivers are needed per 24 hours. (Lau, 2018;Wang et al, 2011). With respect to inland waterway transport no good data was found. On top of that, in Seo et al. (2017) was shown that the total transport time via inland waterway transport from Chongqing to Shanghai can take up to 15 days. Due to this long transport time, inland waterway transport in China is mostly used for bulk transport. Furthermore the modal share of inland waterway transport very low. Guo. & Yang (2017) states that the share is only 1%. With respect to rail transport in China it is very difficult to have a detailed general cost function for the whole country as each Chinese province has a different rail cost structure. Therefore an average cost of $0.65/Km/FEU will be used. For container handling the cost is set at $44/FEU. (Besherati et. al, 2017; Guo et. al, 2017; Monios & Wang, 2013; Seo et. al, 2017)[**].

Based on the above information the following cost function for rail transport can be determined:

$$C_{T,i}^{CN} = 0.65 * D_{Rail} + C_i^{Cargo} * TT_{Rail} + C_H^{CN} \quad (2)$$

** These value was also checked with a Eurasian rail operator and it was found that it was a realistic value (Pottharst, personal communication, 12/05/2018).

In this formula $C_{T,i}^{CN}$ is the out of pocket cost for rail transport in China, D_{Rail} is the rail distance, TT_{Rail} is the transport time for rail transport in China and C_{H}^{CN} is the inland terminal handling cost.
From Shi et al. (2014) was found that 9% of the total hinterland transport in China is rail transport and 91% road transport. Therefore the aggregated hinterland cost in China can be estimated with the following function:

$$C_{HL,i}^{CN} = 9\% * C_{T,i}^{CN} + 91\% * C_{R,i}^{CN} \quad (3)$$

With respect to the cargo cost the following additions were made to the model. Firstly the inventory cost of cargo type i being in transit ($C_{Invertory,i}$) is being determined by the following formula:

$$C_{Inventory,i} = \frac{D_{rate,i}+V_i^{Cargo}}{365} * TTT \quad (4)$$

In this formula $D_{rate,i}$ is the deprecation rate of cargo type i (%/year), V_i^{Cargo} is the value of the cargo shipped ($/cont) and TTT is the total transit time (days). Table 3 contains the cargo value data for cargo types going from China to Europa and from Europe to China.

Table 3: cargo value data

	China to Europe	
	USD/FEU	USD/FEU
Capital equipment & Machinery	91,302	64,920
Chemical products	65,137	52,619
Consumer Fashion Goods	269,071	72,845
Consumer personal & household goods	43,497	20,862
High tech	333,451	147,785
Land vehicles & parts	62,721	46,867
Machinery and parts	99,630	54,335
Raw materials, industrial consumables & foods	21,119	28,642
Pharmaceuticals	22,612	37,836

Source: Damadoran, 2018 and Hurkmans(2018)

Besides the Chinese hinterland modes, also four relevant Chinese ports are incorporated in the model: Shanghai, Ningbo, Dalian and Yantian. For these ports the port dues, pilotage cost, tug boat cost and handling cost are collected and added to the model. These ports are added to the model because they could potentially be used as part of the considered maritime transport chains between Asia and Europe.

6. Calculation results and comparison of the selected routes

In this section three different analyses are made. In the first one, the total generalized chain cost from 6 different Chinese origins to one European destination (Lodz, Poland) via the Alashankou/Khorgos land route and three maritime routes(via southern European port, Hamburg – Le Havre range port and Gdansk) are calculated. The purpose of this analysis is to illustrate the impact of the location of the origin in China on the route choice, that is the route with the lowest generalized chain cost. Secondly an analysis will be made in which three different destinations in Europe are considered (Lodz, Duisburg and Munich) and how this affects the route choice. The third analysis focusses on one specific route (Chongqing - Duisburg) but considers three cases: the impact of using reefer containers because of the harsh temperatures on the land route in either the winter or summer; the impact of having a backhaul ;and the impact of the value of the cargo.

6.1 Impact of the location of the Chinese region of origin on the route choice

In the first analysis the total generalized chain cost are calculated for six different Chinese regions (Xinjiang Uygur (Urumqi, 1), Liaoning (Yiwu,2), Chongqing (3), Sichuan (Chengdu, 4), Heilongjiang (Harbin, 5), (Zhejing (Shenyang ,6)) with a destination in Europe (Lodz, Poland) for three maritime routes and a land bridge:

- Chinese region to a Chinese port and via Polish port (Gdansk) to Lodz;
- Chinese region to a Chinese port and via Southern European port (Koper) to Lodz;
- Chinese region to a Chinese port and via the HLH port (Rotterdam) to Lodz;
- Chinese region via the Alashankou/Korgos land bridge to Lodz (route 1 form table 2) or via the Manzhouli to Lodz (route 2 form table 2)

The calculations are made for different cargo types. The results of the calculations for Xinjiang Uygur (main city of Urumqi) can be seen in table 4.

Table 4: Total generalized chain cost for transporting a FEU container from Xinjiang Uygur to Lodz ($/FEU)

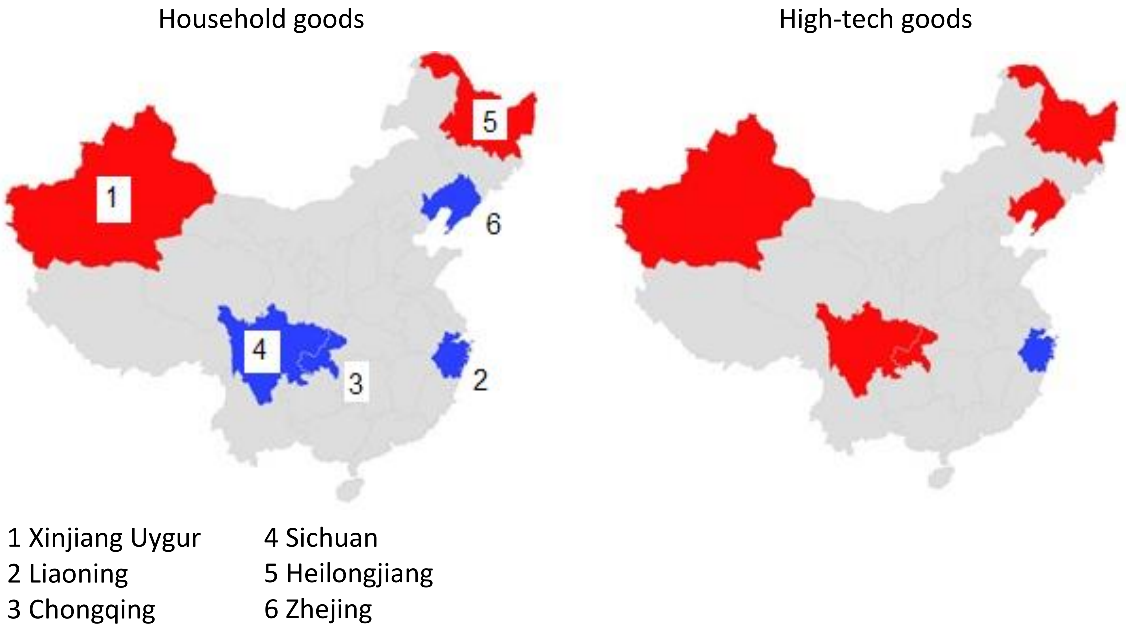
Product type	**Route**			
	Maritime			**Land bridge**
	Gdansk	**Koper**	**Rotterdam**	**Alashankou/Khorgos**
Capital equipment & Machinery	8,494	8,969	9,742	4,647
Chemical products	7,733	8,285	8,752	4,439
Consumer Fashion Goods	8,461	8,941	9,442	4,638
Consumer personal & household goods	6,766	7,031	7,435	4,058
High tech	12,982	14,100	14,864	6,206
Land vehicles & parts	7,636	8,020	8,474	4,358
Machinery and parts	7,904	8,325	8,795	4,451
Raw materials, industrial consumables & foods	6,983	7,277	7,693	4,133
Pharmaceutical goods	7,886	8,304	8,773	4,445

From table 4 can be concluded that the total generalized chain costs are the lowest for the land bridge for all product types. The cost of the maritime route via Gdansk is always the lowest for all three considered maritime routes. This is mainly due to the geographical location of Lodz, close to the port of Gdansk.

For the five other Chinese regions the same calculations are made. The results are plotted in the maps in figure 8. For the regions of Heilongjiang (Harbin, 5) and (Zhejing (Shenyang ,6) the Manzhouli land bridge is used instead of the Alshnakou/Khorgos one. There is a map for household goods and one for high-tech products. In these maps two colours are used. Red means that the land route has the lowest generalized costs, while blue means that one of the maritime routes has the lowest generalized chain cost.

Based on the results of figure 8 the following observations can be made. Firstly, Chinese regions that are more inland located will have lower generalized chain cost when using the land bridge, while for the regions located closer to the main Chinese ports use will be made for the maritime route. Another important observation can be made regarding the impact of the value of the cargo. For high-tech cargo (higher value of the cargo, which means a higher opportunity cost during transport) more use will be made of the land bridge then for household goods, which have a lower opportunity cost during transport. This is also observed in reality, where HP is using the land bridge from Chongqing to Europe for shipment of their computers to the European market.

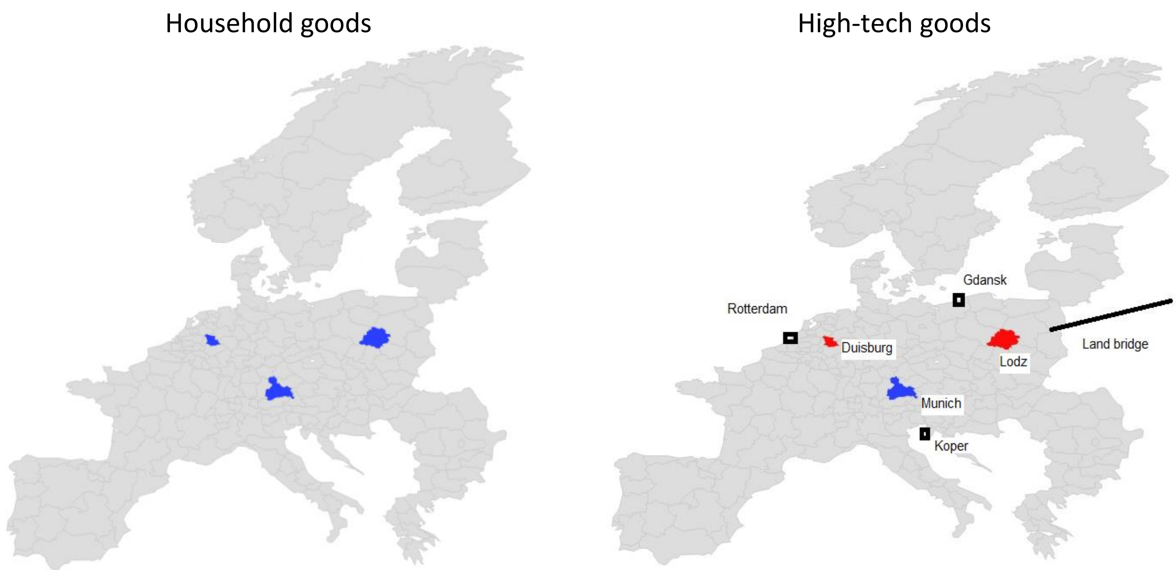
Figure 7: Generalized chain cost comparison between Chinese hinterland regions and Lodz (EU) (Left= household goods, right = high-tech equipment)



6.2 Impact of different European region on the route choice

For the second analysis the generalized chain cost are calculated for chains going from Chongqing to Duisburg, Munich and Lodz. The results can be seen in figure 8. The calculations are again done for household goods and high-tech goods.

Figure 8: Generalized chain cost comparison between European hinterland regions and Chongqing (China) (Left= household goods and right = high-tech equipment)



In figure 9 can be seen that for household goods a maritime route either via Rotterdam (Duisburg), Koper (Munich) and Gdansk (Lodz) has lower generalized chain costs than the land bridge. For high-tech goods the picture is different. For Duisburg and Lodz the land bridge is a better alternative (lower generalized chain cost) than the maritime routes . For Munich the maritime route via Koper has the lowest generalized chain cost.

6.3 Sensitivity analysis of the obtained results

There are some elements in the analysis that deserve some further attention:

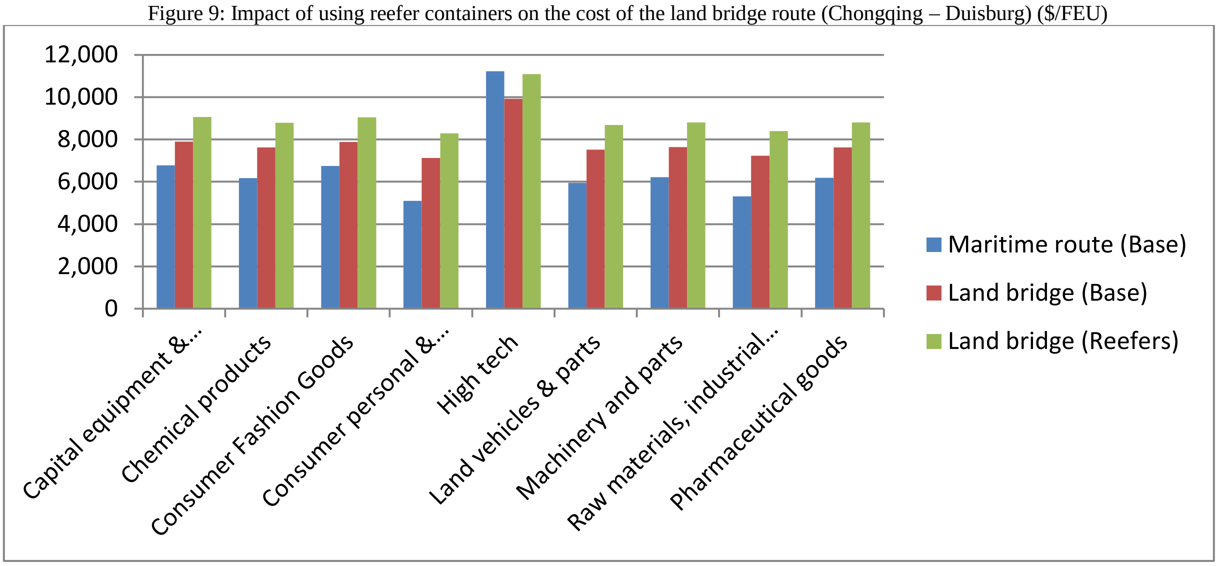
- The impact of using reefer containers to protect the cargo during the harsh condition while using the land bridge.
- The impact of having a backhaul for the land bridge.
- An increase in the value of the cargo shipped from China to Europe.

The calculation are made for the transport chain from Chongqing to Duisburg.

6.3.1 The impact of using reefer container

In figure 9 the results of the calculations are shown when reefer containers are used to keep the temperature at a constant level for certain cargo types.

Figure 9: Impact of using reefer containers on the cost of the land bridge route (Chongqing – Duisburg) ($/FEU)

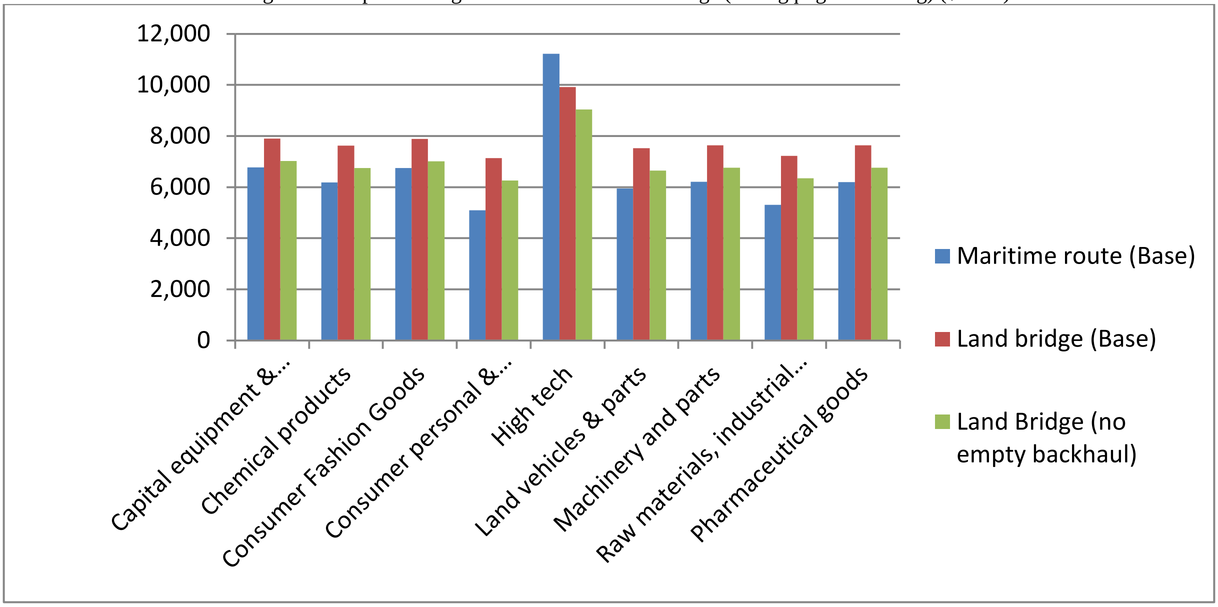


If the cost for using a reefer container are taken into account it can be observed that the generalized cost of the land bridge will increase so making it less attractive. For high tech goods the land bridge is still a suitable alternative for the maritime route although the cost difference is becoming very small.

6.3.2 The impact of having a backhaul

The results of the calculation of having a backhaul and not having to include the cost of an empty backhaul can be seen in figure 10. This situation can occur when trade volumes between China and Europe are more in balance.

Figure 10: Impact having a backhaul on the land bridge (Chongqing – Duisburg) ($/FEU)

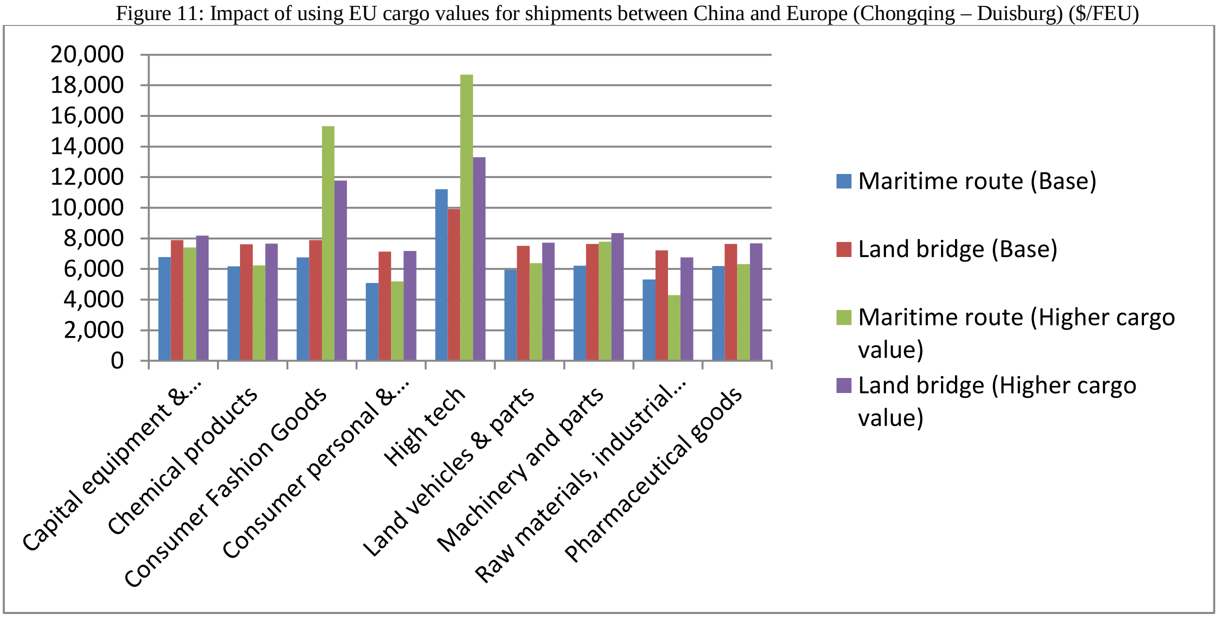


Having a backhaul implies that the cost for the land bridge are decreased. This makes that the land bridge becomes more attractive. For the transport link between Chongqing and Duisburg it can even be seen that for capital equipment, machinery, and consumer fashion goods the cost difference between the maritime route and the land bridge is becoming very small. So if the trade balance between China and Europe is more balanced, i.e. also cargo will be shipped from Europe to China, more cargo types can be transported via the land bridge.

6.3.3 The impact of an increase in the value of cargo shipped from China to Europe

Figure 11 shows the results of the generalized chain cost calculations if it is assumed that in the future the value of the goods shipped from China to Europe will be the same as the value of the cargo from Europe to China. This situation can occur when the labour cost in China to continues to rise.

Figure 11: Impact of using EU cargo values for shipments between China and Europe (Chongqing – Duisburg) ($/FEU)



From the obtained results can be concluded that for certain cargo types such as, consumer fashion goods and high tech goods increasing the level of the value of the goods shipped from China to Europe makes the land bridge more attractive than the maritime route. For other cargo types like machinery and parts and capital equipment the differences in generalized chain cost between the land bridge and the maritime route is reduced. This makes that the land bridge is increasing its competiveness towards the maritime route. For other cargo types like household goods, increasing their value has hardly any noticeable impact.

The sensitivity analysis showed that the obtained results in section 6.1 and 6.2 depend on factors such as using a reefer container to protect the cargo, the trade balance between Europe and China and the cargo value. Generally it can be concluded that if the Chinese economy is transforming to one in which more high-end products are produced and consumed then both the value of the cargo is increasing and the trade balance between China and Europe is more balanced. This situation will make, for some cargo types, the land route more attractive. However, if reefer containers are needed on the land route, its competiveness with the maritime routes will decrease.

7. Conclusions

This paper dealt with the potential of an all-rail based solution on the China-Europe connection as an alternative for the traditional maritime route and the land-sea route. The focus is on the generalized costs as they are the basis for the pricing strategies of the operators on the routes. The Belt and Road policy initiative as a main driver is the starting point for the specification of the corridors and the scenarios to be considered. Equally, the barriers on the Belt and Road path were identified. With that information, a number of scenarios of future rail development on the connection were derived, which were the basis for the calculation of the route generalized costs.

The attractiveness of the land bridge depends on several factors. First of all there is the geographical location of the origin and destination of the transport chain. Secondly there is the effect of the different types of cargo. It can be concluded that the lower the value of the transported cargo, the larger the catchment area of the maritime routes between China and Europe. In this case only transport chains from the West of China to the Eastern regions of Europe (regions that are relatively far away from the major container ports) have a potential for using the land bridge. However, if the value of the cargo increases the catchment area of the land bridge becomes larger. This is also observed in reality where HP is shipping high-end products from Chongqing to Europe.

The obtained results of the generalized cost calculations depend on factors such as using a reefer container to protect the cargo, the trade balance between Europe and China and the cargo value. Generally it can be concluded that if the Chinese economy is transforming to one in which more high-end products are produced and consumed then both the value of the cargo is increasing and the trade balance between China and Europe is more balanced. These situation will make, for some cargo types, the land route more attractive. However, if reefer containers are needed on the land route, the attractiveness of the land route will decrease.

Although the generalized costs will have an impact on the success or failure of a land route, other factors can be decisive. Market power and pricing strategies in the maritime sector can affect the pricing and profitability of the operators of the land route. Furthermore geopolitical factors can make the land bridge less reliable than the maritime route. This means that only if the land bridge can offer a reliable transport service, it can be an alternative, for certain cargo types and trade relations, for the current day maritime transport chains.

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