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Optimization of container transport routes

Abstract

An efficient and sustainable intermodal transport of containers requires the optimization of transportation costs and time while minimizing greenhouse gas emissions. For these purposes, within the DBS Gateway Region project, a Pilot Action has been performed focused on the sustainable intermodal transport of containers in the DBS (Danube Black Sea) region. The Pilot Action included two main activities: development of a multi-criteria route optimization application for container transport and tracking and tracing of a container on an intermodal route from China to Serbia to detect the existing bottlenecks and provide recommendations for the development of sustainable intermodal transport in the DBS Gateway Region.

Keywords: application, container transport, route optimization, sustainable

Introduction

Containerization plays a crucial role in freight transport worldwide, with a constant tendency of growth. Increased number of business entities involved in the process, improved coordination and transport management enabled the achievement of economies of scale in door-to-door modality, all of which led to cost savings and profit increases.

Transportation costs and transit time are the two most commonly considered problems in container transport. Also, carbon dioxide emissions can no longer be

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ignored. On the one hand, companies have a moral obligation to operate sustainably; on the other hand, customers become increasingly aware of the enormous impacts on the environment. Therefore, efficient intermodal transportation of containers requires the optimization of transportation costs and time, while considering the amount of carbon dioxide emissions to operate in a sustainable way (Bernhofen et al. 2016).

The DBS (Danube Black Sea) Gateway Region Project aims at supporting the Danube-Black Sea region to become an attractive gateway region for maritime and inland waterway transport between Central Europe and the Black Sea, the Caspian, and the Far East. Therefore, within the project, a Pilot Action was performed focused on the sustainability and optimization of the intermodal transport of containers in the DBS (Danube Black Sea) region.

The Pilot Action included two steps:

- First, the tracking and tracing of a container from China to Serbia, via the Port of Constanta and the Danube River. Here the aim was to gather all relevant transport data, as well as collect all relevant data from logistic service providers for other alternative routes, China to Serbia via ports: Koper, Rijeka, Bar and Piraeus, to detect existing bottlenecks and provide recommendations for the development of the sustainable intermodal container transport in the Danube Black Sea gateway region.
- Second, the development of an open-source web-application using multi-criteria decision making (three criteria: price, time, emissions) to compare different available intermodal transport routes from an origin to a destination of cargo flows, considering different types of containers and more potential shippers, and to suggest an optimal solution for the given criteria. The application represents a tool that can provide companies with the ability to make decisions about transport routes, taking into consideration all three optimization criteria, depending on the current importance of each criterion defined through the weight coefficients (DBS web platform 2019).

Based on the data gathered from the tracking and tracing of a container, as well as the data collected from the logistic service providers, a database with all relevant information was created. The database was used for testing the application as well for the detection of all existing bottlenecks on the Danube Black Sea intermodal route.

The present paper describes the developed route optimization application, including its testing results for the defined scenarios, as well as the lessons learned from the pilot action and resultant recommendations related to the removal of the existing bottlenecks on the Danube Black Sea intermodal route.

The application

Most of the route optimization approaches are using only one decision-making criterion, usually the transportation cost (Infante et al. 2009; Francesetti 2005; Han et al. 2011). Many researchers also considered multi-criteria decision making in route optimization, using mostly transportation costs and time as the main criteria (Lam and Gu 2013; Yang et al. 2013; Rajkovic et al. 2015).

The developed application enables multi-criteria analysis of potential intermodal routes using three criteria: transport costs, transit times and greenhouse gas emissions during the transport of containers, considering both the maritime and inland transport networks.

The application is developed as open-source with a database that can be continuously updated by the stakeholders with input parameters such as transport distances per mode of transport; transportation costs per mode of transport, container type and gross weight of the container; transportation time for different route sections per different transport modes; available logistic service providers for the selected services on the entire route or particular route sections; etc.

The application enables:

- the simple definition of the weight that each criterion has in each route optimization iteration;
- the efficient analyses of several permissible solutions, in terms of more widely adopted heterogeneous criteria, taking into account both the maritime and inland transport networks, considering at the same time different modes of transport, different types of containers and various available logistic service providers;
- generation of not only the one optimal solution but the ranking of the three best potential routes for the given parameters and criteria weights.

Figure 1: *The DBS route optimization open-source application*

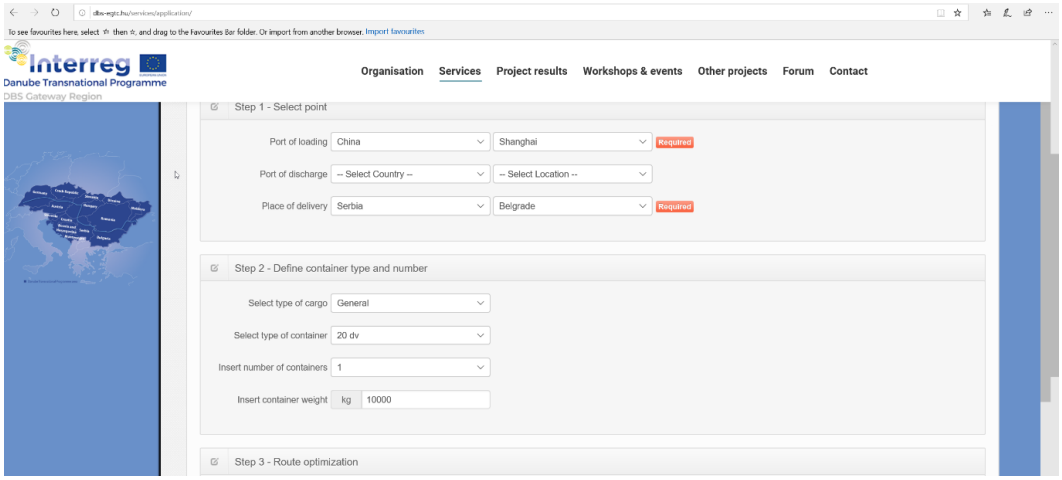
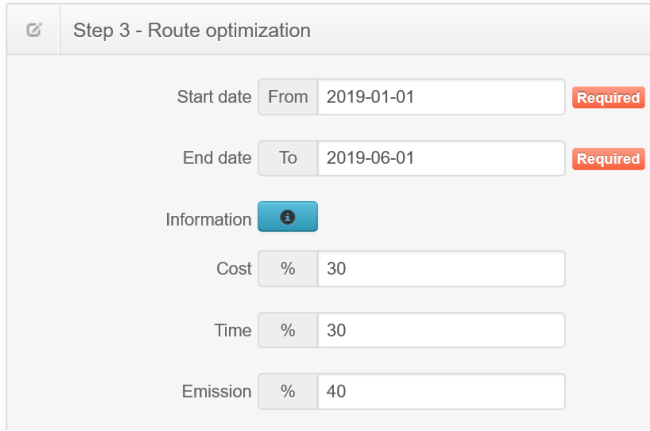


Figure 2: *Selection of the weight of the criteria in the route optimization application*



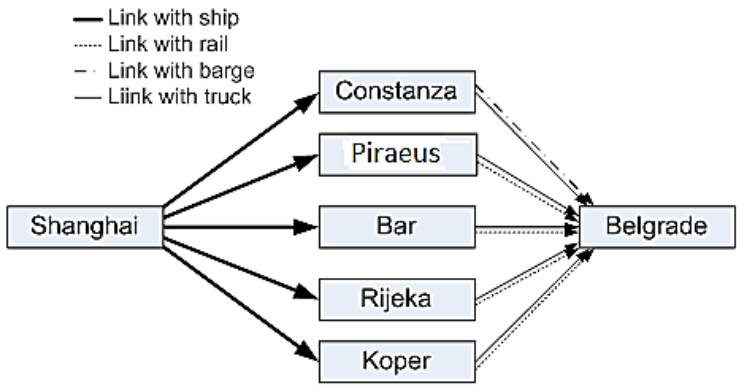
The application was uploaded to the DBS Gateway Region web platform in June 2019. It is supported by the database that comprehends the transport data gathered through the DBS Pilot Action (tracking and tracing of a container from China to Serbia via the Port of Constanta and the Danube River; interviewing logistic service providers in the DBS region).

Route optimization case study

Selected transport routes from China to Serbia from the logistic service providers perspective

Intercontinental container transport chains, in most cases, consist of the main – maritime – transport route section and the first and last transport route section using different modes of transport (road, rail or inland waterway transport – IWT). The main objective of the case study was to determine the optimal container transport route between China and Serbia if the starting point in China is the Port of Shanghai and the endpoint in Serbia is Belgrade including potential transhipment ports: Rijeka, Bar, Koper, Piraeus, and Constanta.

Figure 3: *Potential intermodal transport routes from China to Serbia*

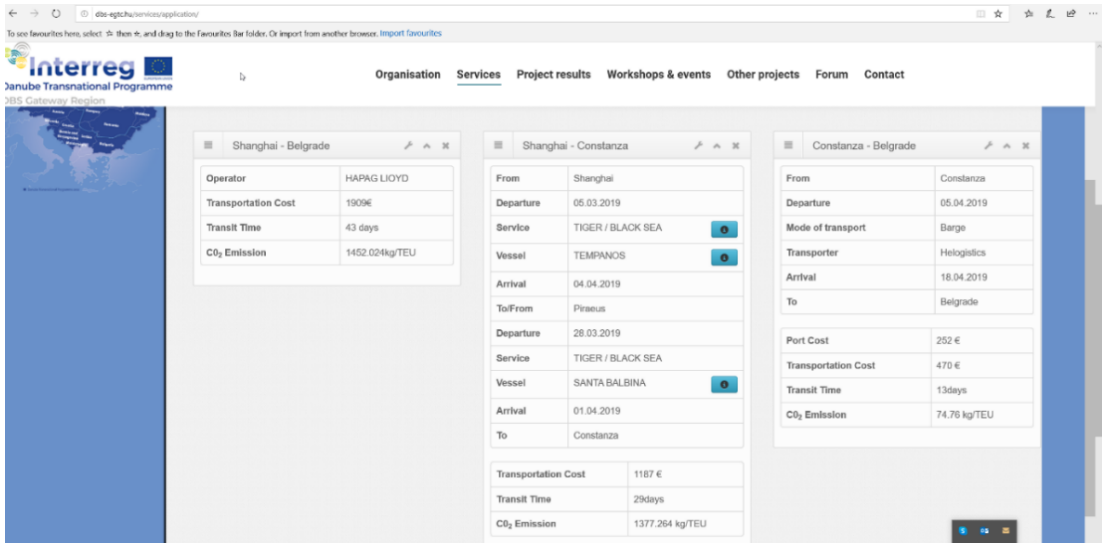


The Port of Shanghai was selected as the world's busiest container port for the case study. Containers were considered to be transported by sea, from the port of loading to the port of discharge, by the six largest shipping companies (Maersk Line – MSK, Mediterranean Shipping Company – MSC, CMA CGM, Evergreen Line-EMC, China Ocean Shipping Company-COSCO and Hapag-Lloyd). Each of the carriers mentioned above transport containers from the port of Shanghai to the nominated ports. As Serbia is a landlocked country, the main hubs for importing containers to Serbia are the ports: Rijeka, Bar, Koper, Constanta, and Piraeus. Belgrade was selected as the point of delivery as it is the capital city of Serbia and the main centre of business activities attracting over 30% of total imports of goods to Serbia (according to the National statistical office, 2016). Belgrade is directly connected with all considered ports by different modes of transport (rail, road, IWT).

The total transport cost from the Port of Shanghai to Belgrade in this research represents the sum of all transportation costs, including ocean freight costs from the Port of Shanghai to the ports in Europe (Constanta, Piraeus, Bar, Rijeka and Koper), port charges, manipulation costs and customs formalities at the ports of discharge as well as transport costs from nominated ports to the terminal in Belgrade using different modes of transport. The transport of containers by rail and barges also includes the costs of container handling at the terminals in Belgrade and local transportation by truck to the consignees (last-mile delivery).

The total transit time is the time from the moment of departure of the container ship from the port of loading until the moment of arrival of the container to the appropriate destination in Belgrade. It includes the time of shipping of the containers at sea, which varies depending on the services of different shipping companies (one shipper can arrive at the port of discharge in up to three ways), waiting time in the unloading port and the time of transport of the container from the port of discharge to the endpoint in Belgrade.

Figure 4: *Presentation of the optimization results of the I scenario*



Total carbon dioxide emissions are the sum of emissions on every transport section depending on the selected mode of transport. The emissions during container handling in the port of loading and discharge are considered negligible.

Based on the data gathered from the vast number of logistic service providers, the database for the Danube Black Sea region was created. The database includes the exact transport distances, transportation and handling costs and times for every section provided by the freight forwarders, defined emissions for every mode of transport per km. It was used for the creation and testing of the open-source web-application.

Route optimization results for the selected case study

The route optimization was performed for the transport of a general cargo TEU (with gross weight 10,000 kg) and six different scenarios depending on the weight of the optimization criteria (see *Table 1*). All values of transportation costs and times (ocean freight costs, terminal costs, etc.) used for calculation in the following scenarios represent average values gathered from freight forwarders for the year 2018.

Table 1: *Route optimization results*

Scenario	Criteria	Weight (%)	Total cost (EUR)	Total time (days)	Total emissions of CO_2 (kg/TEU)	Operator	Through the port	Mode of transport – delivery
I	Costs	100	1909	43	1452.024	Hapag - Lloyd	Constanta	IWT
	Time	0						
	Emissions	0						
II	Costs	0	2488	30	3167.5	Hapag - Lloyd	Koper	Rail
	Time	100						
	Emissions	0						
III	Costs	0	1920	48	1405.908	MSC	Constanta	IWT
	Time	0						
	Emissions	100						
IV	Costs	50	2229	31	3160.53	COSCO	Rijeka	Rail
	Time	50						
	Emissions	0						
V	Costs	30	2119	33	1515.558	COSCO	Rijeka	Rail
	Time	30						
	Emissions	40						
VI	Costs	60	1909	43	1452.024	Hapag - Lloyd	Constanta	IWT
	Time	20						
	Emissions	20						

The results of the route optimization testing prove the complexity of decision making when more than one criterion should be considered.

According to the defined weights of the selected criteria, different scenarios have different optimal solutions while the range of transportation costs, time and emissions significantly differ among the scenarios.

However, if both environmental and economic optimizations are performed, further development of the sustainable intermodal transport routes can be ensured.

Recommendations for the development of the sustainable intermodal container transport in the DBS Gateway Region

In Northern and Western Europe, container transport on inland waterways functions at a high level with high frequency. There are various reasons for this situation: regulated waterways, modern terminals and warehouses, the existence of high-frequency liner services, fast turnover of ships, developed economic activity, branched channel networks along waterways, availability of ships, developed port infrastructure, distance from port/terminal to final destination, economic activity of the region, distance of commercial centres to waterway/ports, simplified administrative procedures, etc.

Possibilities for container transport on the middle and lower Danube were considered numerous times due to the advantages of inland waterway transport: lower transportation costs of water transport in comparison to road and rail transport, less congestion of the infrastructure, possibility of transporting large container lots through individual and frequent transportation, possibility of transporting "heavy containers" over the allowed road transport limits, possibility of more accessible transportation of special containers, possibility of significantly cheaper transport of empty containers, and the environmental benefits. Despite the advantages, a realization of container transport on the middle and lower Danube and the surrounding inland waterways generally ends with sporadic attempts and theoretical discussions.

Within the DBS Pilot Action, tracking and tracing of a container from China to Serbia were carried out. All relevant transport data were collected, reviewed, and summarized, to serve as a basis for the detection of existing bottlenecks and for providing recommendations for the further development of intermodal transport in the Danube Black sea region. The Pilot Action pointed out that aside from the environmental advantages, transportation time and costs of the intermodal route via the Black Sea port of Constanta and the Danube River were not competitive to alternative routes. The following main bottlenecks and obstacles were recognized: inadequate fairway conditions, underdeveloped container terminals in the Danube ports, unsuitable container handling equipment in the ports, non-existence of container liner service

or carriers with the direct services for container transport from the China Main Ports (CMP) to the Port of Constanta – without container transhipment, high transportation costs and long waiting times in inland waterway transport due to the small container lots, complicated administrative procedures in ports and at border crossings, long transport times due to the ships low speed and high transport price due to the long turnover of ships, not efficient hinterland connections of the Danube ports to the economic centres in the region, etc.

Based on the detected bottlenecks and obstacles, the following recommendations for accelerating the development of sustainable intermodal container transport via the Black Sea and the Danube are defined:

- Ensure a passable fairway of the adequate category with a minimum draft of 2.5 m through the entire year.
- Develop modern three-modal logistic terminals on waterways with adequate container handling equipment.
- Establish regular container liner service 2 to 3 times a week in both directions.
- Shorten transit time and fast-turning boats;.
- Achieve a competitive price on inland waterways with rail and road transport from the seaports, first through subsidizing water transport as the most sustainable one and later through the economy of scale.
- Reduce administrative formalities in ports and border crossings.
- Organize fast and economical shipping of goods from the ports to the final destinations;
- Establish direct service from China Main Ports (CMP) to the Port of Constanta – without container transhipment by at least one logistic service provider.
- Use of EU development financial instruments – funds and budgets for implementation of development projects focused on infrastructure development, introduction of new services and networking of all transport modes.

If the recommendations listed above were implemented, both transit time and transportation costs on the intermodal container route from China to Serbia via the Port of Constanta using IWT would be significantly improved, making the route both environmentally and economically sustainable.

Additionally, we would like to point out that:

- In addition to Constanta, the other Black Sea ports (Burgas, Varna, Galati) also have the potential to offer alternative transport routes between China and Serbia (and the rest of the region and Europe).
- The development of container transport in the Danube could provide the Black Sea ports easier access to the hinterland and increase their competitiveness. Also, the economy and the international trade of the hinterland could be improved by a better connection with the ports which complies with the goals of the project DBS Gateway Region.
- Apart from the further development of IWT infrastructure, the development of efficient and safe rail and road infrastructure is also a prerequisite for the increased competitiveness of the Danube and the Black Sea ports, mainly within the context of creating efficient backup routes in the case of unfavourable navigation conditions).

Conclusions

Containerization plays a very important role in freight transport worldwide with a constant tendency of growth. Although, transportation costs and transit time are two of the most commonly discussed problems related to container transport optimization, greenhouse gas emissions and climate change, one of the biggest challenges of our generation, can no longer be ignored when planning and optimizing container transport routes. Therefore, within the DBS Gateway Region project, an open-source web application has been developed to enable the multi-criteria analysis of potential container transport intermodal routes using three criteria: minimum transit times, lowest transport costs and minimum emissions. The application was tested for six scenarios in the case study of the container transport route optimization between China and Serbia, considering the potential transhipment ports of Rijeka, Bar, Koper, Piraeus, and Constanta. Testing the application proved the multi-criteria approach as well as the application useful and effective.

Additionally, a detailed analysis of the bottlenecks of the intermodal container transport route from China to Serbia via the Danube River and the Black Sea ports was performed representing the basis for the recommendations for the removal of the bottleneck and the further development of sustainable intermodal transport in the region.

The follow up of the presented research should primarily consider an update and extension of the database created within the DBS Gateway Region project, so that the application for the optimization of the container transport routes can be further tested for other routes in other geographical regions.

At the same time, recommendations given for the development of the intermodal container transport route via the Black Sea and the Danube River should be implemented in all Danube and Black Sea countries with the support of national and EU funds, as well as public-private partnerships, to ensure sustainable development of intermodal transport in the DBS region.

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