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Energy Efficiency of Container Cargo Flow in Largest East Adriatic Ports

Abstract

Modern cargo flow nowadays requires proper analysis in order to optimize the costs and environment impact. To properly assess the ports at eastern Adriatic region transport energy efficiency and emissions were analysed, including both sea and land transport. For the sea transport Otrant gate was chosen as an entry point in Adriatic Sea. The analysed ports are Trieste, Koper and Rijeka as well-established container terminals and ports of Zadar and Ploče as terminals which in future may provide significant service. For the land transport, using both truck and train, Budapest was chosen as a final destination due to its location further in land at similar distance from all selected ports. As a cargo unit one 10 tonne TEU unit was used. The purpose of this analysis was to determine required energy to transport that one unit and emissions which such transport produce, not a volume or speed of transport. All the calculations were made using EcoTransIT calculator. The results showed that north Adriatic ports have one of the best positions in terms of efficiency of land transport, however southern Croatian ports have to develop transport infrastructure, mainly railroad, to be considered as a notable stakeholder.

Key words: EcoTransIT, Adriatic Sea, energy efficiency

1. Introduction

Container terminals in Adriatic Sea are one of the most prosperous terminals for receiving cargo from the Far East. The benefits of geostrategic position are shown through many analyses. In paper [1] analysis showed that redirecting container flow

to north Adriatic container terminals can be justified by economic, transportation and environmental factors. Also, paper [2] showed that if container flow redirected through Adriatic terminals is 20% less distance and fuel consumption in comparison with north Europe terminals. Paper [3] shows that trends are in bigger container ships where these ports will have to work together in order to attract cargo. But despite the call to work together, competition between these terminals will continue and may intensify. This is one of the indicators that Croatia may enter this competition with more container terminals. The modernisation of existing and new terminals should follow container expansion where berth infrastructure and superstructure archive higher subsystem utilisation and productivity [4]. Modern container terminals are not just gateways but a place where important value adding and logistics activities are taking place [5].

Described benefits may be obtained if more Croatian ports are included in container cargo handling. Ports of Trieste, Koper and Rijeka have the most of the TEU units handled, however two Croatian ports, Zadar and Ploče, have the potential to attract the cargo and to distribute it to Eastern Europe. Beside economic, nowadays environmental conditions dictate the future of the transport. This paper analyses transport efficiency from these five terminals and to its connection to background with the main goal to determine which port is the most energy efficient in transporting one 10 tonne TEU unit in comparison to others and may that efficiency be improved. Also, in analysis the emission of CO_2 gas has been analysed in order to determine environmental footprint of each route.

2. Overview of main sea traffic corridors in eastern part of Adriatic Sea

Eastern part of Adriatic Sea is dominated by following container ports: Trieste, Koper, Rijeka and Ploče. The handled cargo and passenger statistics report from March 2020 indicates that Trieste and Koper have the largest TEU units handled followed by Rijeka and Ploče [6]. The reason for this may lie in infrastructure, road and rail network connecting the port, availability for the various vessel sizes and etc. Also, each of these ports have different characteristics which makes differences between them.

Table 1: Overview of analysed container terminals technical information

	Trieste	Koper	Rijeka	Ploče
Max. draft	18	14,5	14,21	14
TEU capacity	900.000	950.000	600.000	60.000
Total berth length [m]	1.370	596	628	280
No. of cranes	7	9	4	3
No. of reefer points	234	432	418	n/a

Source: [7, 8, 9, 10]

Container terminal Trieste is located in the north part of Adriatic Sea and has the largest available ship draft and berth length. This is the largest terminal in this part of Adriatic and can accept the largest container ships. It has two cranes less than Koper, however all of seven cranes are post-panamax[1] [2]. Container terminal Koper is the second terminal by draft and first by annual TEU capacity. Total berth length is similar to Rijeka, however it has more cranes, of which six are post-panamax[1] and three are panamax[1] or smaller [3]. Container terminal Rijeka by size is similar to Koper, however it has less terminal capacity and less cranes. There are only two post-panamax[1] cranes and two pamanax[1] cranes. Container terminal Ploče is the located further south and it is the smallest of all. Despite available depth cranes and berth length are limiting factor for this terminal. Terminals in Trieste, Koper and Rijeka are very near and cover similar background area and differences are in transport means used for connection with the background. Container terminal Ploče gravitates to different area, however background connection could interfere between these ports.

Table 2: Four-year TEU turnover statistics

	2015	2016	2017	2018	2019	2020
Trieste	443.882 teu	449.481 teu	546.660 teu	625.767 teu	688.649 teu	687.921 teu
Koper	790.736 teu	844.776 teu	911.528 teu	988.501 teu	959.354 teu	945.051 teu
Rijeka	200.102 teu	214.348 teu	249.975 teu	260.375 teu	305.049 teu	344.091 teu
Ploče	20.829 teu	22.961 teu	28.168 teu	31.182 teu	28.726 teu	25.717 teu

Source: [11, 12, 13, 14]

Number of TEU turnover gives us different perception of analysed terminals. Container terminal Koper has the largest number of TEUs handled, however this port is the only cargo entry port for Slovenia and it is expected that all transport will come through this port. If we compare Slovenia with surrounding countries, Croatia has additional two terminals and Italy thirty-five at Adriatic Sea [11]. The least amount of TEUs turnover has, as expected, Ploče. That is result of insufficient container terminal infrastructure and poor traffic connection to its natural background. Container terminal Rijeka is the main entry point for containers in Croatia, however poor rail infrastructure limits further growth. All these terminals are also limited by space since they are in or near to city limits. Container terminal Trieste and Koper have good road and rail connection to its background compared to Rijeka and Ploče which have good road connection but poor rail connection.

All Croatian ports are connected via highway and railway with background, which is in this analysis is Budapest, the main hub for Eastern Europe. Only port of Ploče mostly gravitates to its natural background through another country (Bosnia and

[1] This refers to old Panama canal width of 32,2 meters

Herzegovina). The port of Ploče gravitates to corridor Vc which directly connects it to Budapest via 746 km long road/highway combination. Alternative route is through Croatia and Hungary which is 846 km long highway. That route is longer, however it has only one border crossing and in it is full profile highway all the way. Rail connection is only through corridor Vc and is 764 km long. Port of Zadar is connected to its background by highway and railway. Full profile highway, 626 km long, is through corridor Vb connected with Budapest. Railroad to Budapest, 732 km long, is connected via Knin and Zagreb. The biggest problem is railroad between Zadar and Knin which is outdated. Port of Rijeka is connected through corridor Vb with Budapest. Road connection is 505 km long full profile highway and rail connection is 564 km long. Port of Koper is trough corridor V connected to Budapest. Rail connection to Budapest is 538 km long and road connection is 625 km long. Port of Trieste is also trough corridor V connected to Budapest. Road connection is 528 km long and rail 607 km long (Figure 1).

Figure 1: Analysed routes from Otrant gate as starting point to Budapest as finishing point
Source: Map layer from Google maps, routes done by authors

3. Analyses of energy efficiency

In order to achieve energy efficiency of container flow, following parameters were selected. Transport is calculated for one 10 tonne TEU unit. Since the cargo flow

is analysed for eastern Adriatic ports the starting point for sea transport is Otrant gate and the final point on land is Budapest in Hungary. These starting and finishing points were selected because the total distances are similar and the differences in segments of transport will show which port is more energy efficient and produces less emissions. The analysed routes are following: Otrant – Ploče – Sarajevo – Budapest, Otrant – Zadar – Zagreb – Budapest, Otrant – Rijeka – Zagreb – Budapest, Otrant – Koper – Maribor – Budapest and Otrant – Trieste – Maribor – Budapest. Land transport is calculated for truck transport (Euro 5 trucks) and for train transport (diesel engines). Train transport is calculated for diesel engines due to electrified train tracks network limitations on certain route segments.

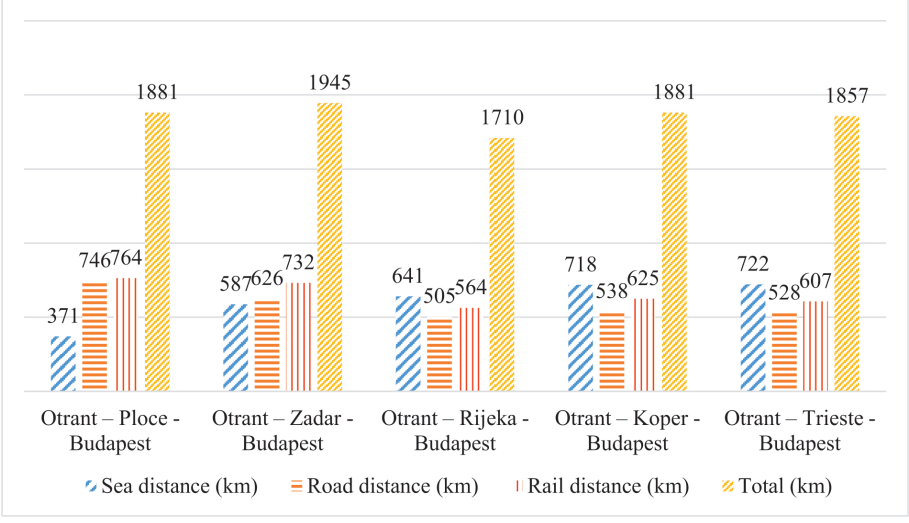

Figure 2: Graphical and numerical representation of distances between starting point to finishing point by analysed means of transportation
Source: [15]

Distances of each route and tis segments are shown in Figure 2. Port of Ploče has the smallest sea distance however the land distance is the largest and the infrastructure is inferior in comparison to others. Port of Zadar is in the middle of Adriatic Sea and has good road connection, however the rail connection is practically non-existent and in bad condition. Ports of Rijeka is closer to Otrant by sea than Koper and Trieste and has excellent road connection. However, rail connection of Koper and Trieste is superior with better infrastructure and connections.

For calculation purposes EcoTransIT World methodology was used [15]. This tool is developed and validated by Institut für Energie- und Umweltforschung Heidelberg gGmbH, INFRAS and Fraunhofer Institute for Material Flow and Logistics. The result of each calculation is transport distance, energy consumption and amount of emissions

(main emission gas CO_2). Emissions calculations include EN 16258 and GLEN compliant calculation which displays emissions both for Tank-To-Wheels (TTW) and Well-to-Wheel (WTW).

For each part of the route energy consumption is calculated for Well-to-Wheel (WTW) basis (Table 4). The starting point is entrance in Adriatic Sea Otrant gate and the finishing point is Budapest, Hungary. The transport is divided in sea section (from Otrant gate to analysed ports) and the land transport is calculated both for road and rail routes.

Table 3. Analysed routes well to wheel energy consumption

Route	Sea transport (Megajoule)	Road transport (Megajoule)	Rail transport (Megajoule)	Total (Megajoule)
Otrant – Ploče - Budapest	345	7579	3216	11140
Otrant – Zadar - Budapest	547	6279	3117	9943
Otrant – Rijeka - Budapest	597	5077	2406	8080
Otrant – Koper - Budapest	668	5433	2661	8762
Otrant – Trieste - Budapest	672	5336	2588	8596

Source: [15]

Segment of each analysed transport mean will show which port is the most energy efficient. Ports in northern part of Adriatic Sea have the larger amount of energy in sea transport. However, the energy of sea transport makes a small part of total consumed energy in analysed routes. That information shows that longer ship voyage doesn't affect total energy consumption, but contributes to its reduction and places these ports in advantage due to shortest land transport route. The second contributing part to reduce energy consumption is developed rail network. Ports Rijeka, Koper and Trieste have developed rail network which connects it with its background. In this case quantity of cargo flow is not analysed, but the availability of rail network and its connections. Road transport is, as expected, the least energy efficient of all three analysed means of transport.

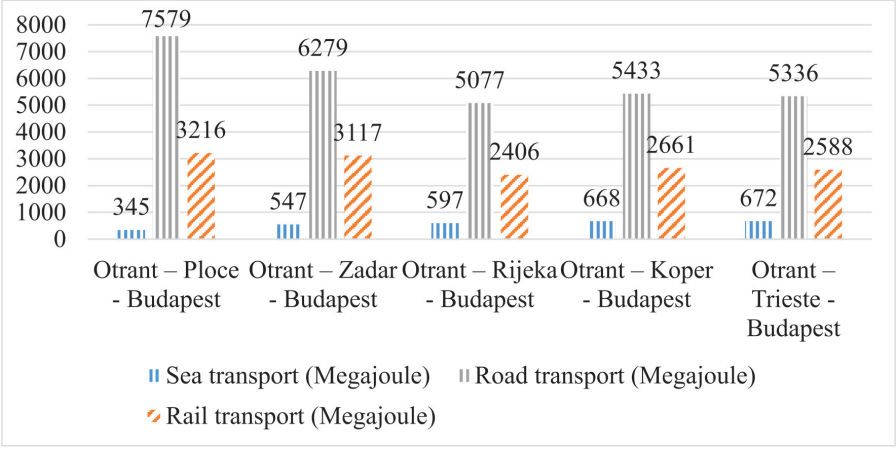

Figure 3: Distribution of energy consumption (WTW) by each mean of transportation at analysed routes
Source: [15]

Also, for each route greenhouse gas carbon oxide CO_2 emission are analysed.

Table 4. Analysed routes wheel to wheel CO_2 emission

Route	Sea transport (tonnes)	Road transport (tonnes)	Rail transport (tonnes)	Total (tonnes)
Otrant – Ploče - Budapest	0.0265	0.56	0.24	0.8265
Otrant – Zadar - Budapest	0.0420	0.45	0.22	0.7120
Otrant – Rijeka - Budapest	0.0458	0.36	0.17	0.5758
Otrant – Koper - Budapest	0.0513	0.39	0.19	0.6313
Otrant – Trieste - Budapest	0.0516	0.38	0.18	0.6116

Source: [15]

In table 4 CO_2 emissions are shown. As it can be seen the smallest amount of emissions is produced by ship transport followed by train transport. Route through Adriatic Sea is relatively small and for ships bound to ports in Adriatic is final stage of voyage. The emissions from ships in this analysis are small fraction of total emission in transport chain. In terms of emissions port location is relative and will depend on port rail infrastructure which, as data show, may reduce emissions in land part of transport. If we compare all segments of transportations from starting to finishing point, route through port of Rijeka has the smallest CO_2 emissions, while route through the port of Ploče despite smallest sea route has the largest amount of emissions due to longest land route.

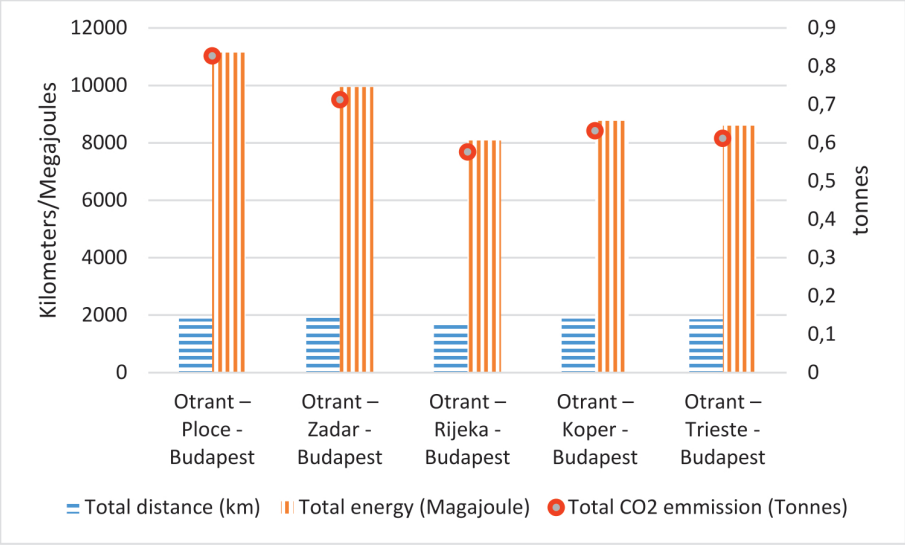

Figure 4: Each route total analysed dana comparison
Source: [15]

If we compare total analysed data (Figure 4) it can be seen that port of Rijeka has the best conditions to transport containers into Easter Europe background. That is followed by port of Trieste and Koper. Ports of Zadar and Ploče despite good position are in disadvantage compared to other three ports. The main reason is the bad rail infrastructure, since the road infrastructure is good, and in case of port of Ploče corridor Vc is passing through another country which is less developed.

4. Conclusion

The TEU handling data shows that port of Trieste, Koper and Rijeka are the busiest container ports on eastern part of Adriatic coast. Despite shown data ports of Trieste and Koper are currently largest container terminals in Adriatic Sea. The main reason is that for each state (Italy and Slovenia) that is the only sea entry port for Easter Europe, equipped with modern gantry cranes, large depth and have developed rail (electric) network (as shown in table 1). Croatia which has the larger coast in eastern Adriatic Sea has more ports which are developed partially. Analysed data show that ports of Rijeka and Zadar have the best potential to become entry port for Eastern Europe. The main drawback of these two ports is railroad network which is outdated and not electrified in its entire length. When that drawback is eliminated the terminals will become more attractive to cargo which will ensure its growth and further modernisation. The advantage of these ports, along with the Ploče, may be less time required for the ship

to arrive in port (compared to ports in bay of Trieste) and using that time as a leverage to a consumed energy.

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