Redirection aspects of Far East – Central Europe traffic flows: Facts, findings and future tendencies

DAVID BRČIĆ*
University of Rijeka, Faculty of Maritime studies, Department of Nautical Sciences, Rijeka, Croatia
e-mail: david.brcic@pfri.uniri.hr
Orcid: 0000-0003-0643-841X

SINIŠA VILKE
University of Rijeka, Faculty of Maritime studies, Department of Maritime and Transportation Technology, Rijeka, Croatia
e-mail: sinisa.vilke@pfri.uniri.hr
Orcid: 0000-0001-9905-505X

SERDJO KOS
University of Rijeka, Faculty of Maritime studies, Department of Nautical Sciences, Rijeka, Croatia
e-mail: serdjo.kos@pfri.uniri.hr
Orcid: 0000-0003-0067-6150

SRĐAN ŽUŠKIN
University of Rijeka, Faculty of Maritime studies, Department of Nautical Sciences, Rijeka, Croatia
e-mail: srdan.zuskin@pfri.uniri.hr
Orcid: 0000-0001-8389-828X

*correspondence and presentation

ACKNOWLEDGMENTS

This research was partially funded by the Project Interreg Italy-Croatia: *Maritime and Multimodal sustainable passenger transport and services* (MIMOSA). Authors are grateful for the availability and of the *Ecological Transport Information Tool* (EcoTransIT), which was used for a part of conducted analyses and research results presented in the paper. We appreciate and support the development of this initiative and valuable tool.

Keywords

multimodal transport, land transportation, fuel cycle process, environmental impact and emissions' mitigation, northern adriatic

Abstract

The multimodal door-to-door transport chain connecting Central Europe with Far East origins predominantly calls the North European ports. However, already the geographic features are dictating the reasonable possibility of routes' redirection via several alternatives through the Mediterranean Sea. This study represents the continuation of the research in terms of analysis and evaluation of the Southern European freight transport flow through the Northern Adriatic. The aim was to elaborate further on the justification of the possible redirection of cargoes via the Adriatic corridor. In these terms, the land segment of the transport chain from ports to the final destination was isolated and analysed. The authors were primarily guided by natural features, that are respective geographical locations and their mutual

distances. For this purpose, container transport on two traffic flows was simulated, with emphasis on the land segment between the second (destination) port and the final destination. Considering the usual freight lines, the door-to-door container transport between origin and destination was selected. Both road and rail transportation modes were investigated, making total of eight simulated scenarios. Besides general parameters, such as distances, time, and fuel consumption, the environmental impact for all scenarios was determined for both downstream and final fuel cycle processes. In these terms, the following environmental parameters were calculated: energy consumption, emissions of carbon dioxide, greenhouse gases, nitrogen oxides, sulphur dioxide, non-methane hydrocarbons, and particulate matter. Results are indicating that, together with a significant reduction of sea transportation impacts on the environment, the eventual redirection contributes to emissions' mitigation and the sustainability of transportation. These results are accompanied by several initiatives in the area. Apart from potential benefits, the findings were discussed from the reliability point of view, i.e. the ability of Northern Adriatic ports and the land infrastructure to successfully take over this task, at least to a certain extent, and finally, in a reasonable future.

1 INTRODUCTION

This paper elaborates and evaluates features of main traffic flows between the Far East and the Central Europe. The emphasis is given on two directions, both passing through the Suez Canal. The aim of this study is to further justify the redirection of transportation goods in terms of various types of savings, including distances, time, and environmental impacts.

Transportation engineering can be defined as a scientific discipline in which the goal is to use specific scientific methods and mathematics with the aim of optimising the relevant transport parameters in the transport of people, living beings, freights, or energy transfer from the initial destination to the final destination [1]. Lang and Wohl [2] point out the existence of at least three specific characteristics of most transportation system engineering and planning problems:

1. Many world regions include millions or more individual person trips and a number of shipments and transhipments of freight,
2. Due to the large number of available transportation technologies, transport routes and the different modes on which they can be executed, regulated and priced, there is a large number of possible acceptable solutions,
3. The goals to be achieved by improving transportation systems are manifold.

In terms of improving the multi-modal transport process of container freights transport by sea between the Far East - Europe and vice versa, this paper is based at above described point 2.

Regarding geographical and sea features, and considering current distribution of Far East – Central Europe traffic flows, the particular shipment can reach its final destination in three possible directions, (Fig. 1):

1. Far East – Suez Canal – North Europe;
2. Far East – Arctic transpolar – North Europe;
3. Far East – Suez Canal – North Adriatic.

Fig. 1. Sea routes connecting the Far East with Europe. Adapted and modified on the basis of [3]

Here, the possibilities of transpolar direction have to be considered to a certain extent. Due to a whole series of new circumstances (including accelerated melting of glaciers in the Arctic ocean, use of icebreakers with a laser system for ice breakthrough), the existing sea route no longer appears as the shortest connection between Europe and the Far East. The possibility of new Arctic, transpolar route could be approximately 30 % - 40 % shorter than the existing routes through the Suez Canal [4]. An additional reduction of 1000 nautical miles can be achieved from Northern Europe to Vietnam [4]. Some of potentially interesting sea routes for navigation across the North Pole in the Arctic ocean are as follows [5]:

1. Transpolar route - which directly connects the Atlantic and Pacific Oceans. It is one of the shortest polar navigation routes of approximately 2105 NM in length and is expected to be significant in 2030,
2. Northwest Passage – has 5 different sea routes,
3. Northern Sea Route which is approximately 40 % shorter than the classic sea route through the Suez Canal on the sea route Busan – Rotterdam,
4. Central Arctic Shipping Route,
5. Arctic Bridge Route – connecting Murmansk and Churchill.

Conducted review [6] notes that Russia[1] imposes tariffs on the Northern Sea Route, the most favourable shipping route because of its acceptable ice conditions. At the same time, Canada imposes no tariffs on the use of the Northwest Passage, which still has the worse ice navigation conditions. There appears a list of at least three causes of increased risk in polar regions, affecting the development of Arctic routes [6]:

- Heavy weather conditions,
- Significant lack of infrastructure, communication, mapping and other related elements,
- Increased chance of human error.

Furthermore, consideration of the Northern Sea Route as internal or territorial waters, or international straits, is undetermined. It can lead to vessel' loss of the right of the innocent passage [7, 8]. Before the Polar Arctic sea route can become a standard, the Polar Code environmental policies have to be. These restrictions will be increasingly comprehensive as the maritime traffic flow grows, with the main goal of protection of the existing nature and wildlife [7]. Despite the reasonable vision of the polar route as a transoceanic, global cargo (sea) direction, and its potential to change global traffic flows, it is still considered as a maritime energy corridor, as well as a long-term issue [8]. Mentioned facts narrow the choice of analysis to two existing directions passing through the Suez Canal.

The possibilities of mentioned redirections primarily rely on natural, geographic features of the particular areas and respective traffic directions, and among the mentioned reductions, they refer to environmental influences as well. In [9], authors considered the redirection of the maritime traffic flow from Far East to the Central Europe through the Northern Adriatic corridor instead of the North European ports. The proposed redirection significantly shortens the door-to-door transportation in both sea and land transport segments. The redirection was justified with means of introduction and development of selection and evaluation of the optimal container transport route by using the multiple criteria analysis, and again, considering features of both geo-traffic flows [10].

The proposed paper represents the continuation of the research dealing with redirection, its justification and challenges of feasibility, as well as potential benefits which may reflect on positive sustainable transportation outcomes. The latter is examined through the prism of green transport initiatives and global and European sustainable transportation strategies' development. The default target is the direct reduction of the door-to-door container transportation costs and the environmental impact, when comparing two traffic flows; North European and North Adriatic. For these purposes, two traffic directions were simulated, based on usual transportation directions and container freights. The findings are presented and discussed in terms of abovementioned savings, and environmental impact reduction.

2 BACKGROUND

2.1 Distribution of Far East – Central Europe traffic flows

Maritime routes' importance and significance are determined by their geographical position, and are influenced by transit geographical elements affecting, besides their psychical locations, the port's link to the hinterland [11]. Central Europe is situated in a strategically significant region with connections to the

[1] The current (February/March 2022) sequence of events was not considered in the study.

Far East via Northern European ports in the north, and the Northern Adriatic ports in the south, respectively.

The selection of ports and transport routes is a product of the commercial policy of shipping companies. The cost ratio and the use of the ship's space are the parameters that are considered in the decision-making process. The cost per unit of cargoes is lower when it is transported by larger container ships. In addition, the costs are more favourable in maritime transport due to the high cargo transit capacity on the routes Europe-Far East, and Far East-Europe [12]. The favourable geographical position of Central Europe favours the expansion of the maritime trade. Large ports in the north of Central Europe on the Baltic and North Sea coasts, as well as small and medium-sized ports along the northern Adriatic coast, are regulating the maritime traffic.

Two shipping routes stand out in the trade between Central Europe and the Far East. The northern European traffic route starts from the ports on the North and Baltic Seas, with the largest ports of Hamburg, Rotterdam and Antwerp, being among the 20 largest container ports [13].

The southern traffic flow is, apart from the eventual transpolar route, the shortest and most economical maritime connection between Central Europe and the Far East, supplying the markets of Central European countries [14] through ports of Rijeka, Koper, Trieste and Venice [15]. Due to their geostrategic and traffic geographic position, the ports of the Northern Adriatic constitute the shortest maritime connection linking Central Europe with one of the largest markets – the Far East (Table 1).

Ports	Singapore	Hong Kong	Shanghai	Busan
Rijeka	7090	8880	9745	10257
Koper	7116	8911	9772	10288
Trieste	7116	8911	9772	10288
Hamburg	9621	11.416	12793	12793
Rotterdam	9343	11138	12515	12515
Rostock	10148	11942	13320	13320

Table 1. Distances (in nautical miles) between Far East and European ports [16]

In addition, it is important to highlight the *Belt and Road initiative* [17], which could lead to the Silk Road of the 21st century. Apart from the *Silk road economic belt*, the proposed *Maritime Silk road* is considered as the connection between the Far East and the Central Europe in a more specific, economic and trade terms. This pattern extends through the Pacific and Indian Oceans and include the Persian Gulf, the Red Sea, the Suez Canal and finally, the Mediterranean Sea [18] (Fig. 2).

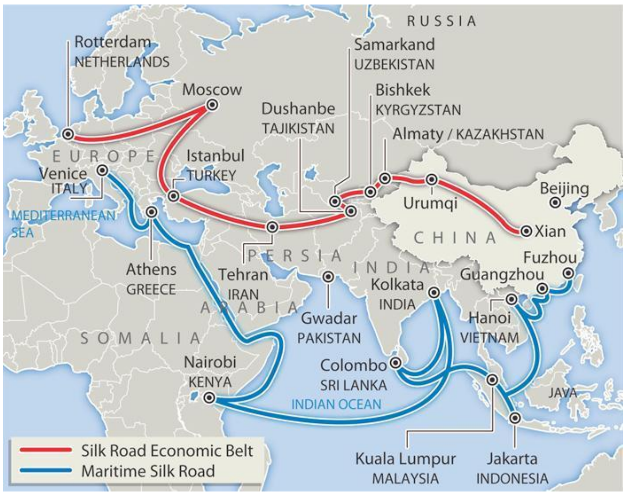

Fig. 2. Silk Road of the 21st century [19]

Directing the flow of goods from the Far East via the Silk Road through Northern Adriatic ports would have a considerable impact on maritime development. In this way, the landlocked Central Europe countries would have the opportunity to trade with the Far East by the shortest route, thanks to the infrastructural development of the hinterland connections. Consequently, the realisation of this route would have an impact on the development of traffic in the ports of the Northern Adriatic [18].

The ports of Rijeka, Koper, Trieste and Venice form an ideal multimodal chain, with variety of logistics services and extensive transportation network. The location of ports offers the possibility of increasing the intensity of cargo flows, thus creating valuable multiplier effects for the Northern Adriatic transport and economic system [20].

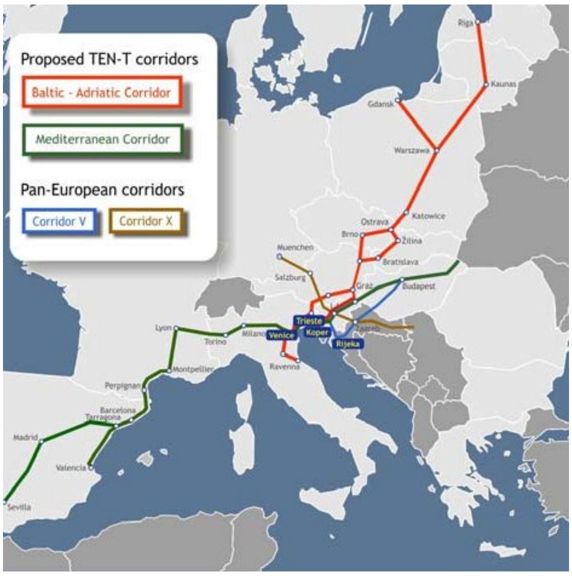

Fig. 3. Connection of TEN-t and Pan-European corridors with the ports of the North Adriatic [14]

The connections of Northern Adriatic ports with Central Europe via the TEN-T and Pan-European corridors are shown in Fig. 3. The North Sea-Baltic Sea corridor TEN -T connects Poland, the Czech Republic, Slovakia, Austria and Italy, while the TEN-T Mediterranean corridor connects Spain, France, northern Italy, Slovenia, Croatia and Hungary [21]. The Corridor Vb, a branch of the Pan-European Corridor V, which connects the port of Rijeka with Budapest via Zagreb, and the Rijeka-Zagreb railroad line are marking the Danube Corridor VII and the Pan-European Corridor X important [22]. These corridors support the development of the Northern Adriatic ports, whose potential depends not only on their maritime role but on their connection to the European transport network. The NAPA (Northern Adriatic Ports Association) port system serves as a strategy for the development of maritime structures and hinterland connections, relying primarily on the location of the Northern Adriatic as the northernmost point of the Mediterranean [23, 18].

2.2 Review of the Northern Adriatic and Northern Europe cargo turnover

The volume of transported cargo traffic is the best indicator of the maritime trade. Analyses of the cargo traffic indicate the constant growth. The growth of container traffic is a result of continuous investments in this type of transport.

Several indicators should be considered when analysing the movement of goods from the Far East to Europe through the Suez Canal [13]. The length of the waterway from the Suez Canal to the Northern Adriatic ports and to central European destinations is significantly shorter when compared to Northern European ports. The existing and alternative distances between the Far East and Central European destinations are shown in Table 2.

Transport	Scenario	Switzerland	Italy	Austria	Spain	France
Maritime (NM)	Existing	10234	10234	10234	10234	10234
	Alternative	8645	8645	8459	8940	8739
	Difference	- 18 %	- 18 %	- 17 %	- 16 %	- 16 %
Road (km)	Existing	614	950	975	1650	579
	Alternative	239	142	354	618	505
	Difference	- 61 %	- 85 %	- 64 %	- 63 %	- 13 %
Railway (km)	Existing	594	925	990	1545	560

	Alternative	239	140	350	600	500
	Difference	- 60 %	- 84 %	- 65 %	- 61 %	- 11 %

Table 2. Connection of TEN-T and Pan-European corridors with Northern Adriatic ports [9]

Table 3. shows the total turnover of processed cargo in the ports of the Northern Adriatic and Northern Europe in the period from 2015 to 2020. The increase in cargo traffic in 2018 compared to 2017 was recorded in the Northern European ports by approximately 2.7 % and in the Northern Adriatic ports by approximately 4 %. In 2019, there was a minimal increase in traffic, while in 2020, Northern European ports recorded a decrease in traffic of 6 % and Northern Adriatic ports of 6.5 %.

Ports	2015	2016	2017	2018	2019	2020
Antwerpen	190.107	198.691	201.202	212.010	214.030	206.319
Rotterdam	436.942	431.944	433.293	441.473	439.631	409.236
Hamburg	27.395	24.474	28.210	28.296	28.867	27.797
Total	654.444	655.109	662.705	681.779	682.528	643.352
Rijeka, Koper, Trieste, Venezia	105.890	107.701	117.056	121.371	122.548	115.205

Table 3. Total cargo traffic in Northern Adriatic and Northern European ports (in thousands of tons) [24-27]

Container traffic is one of the most common forms of transport. In 2021, container traffic on the Europe-Asia-Europe trade route amounted to 26.3 million TEUs (Fig. 4) [28].

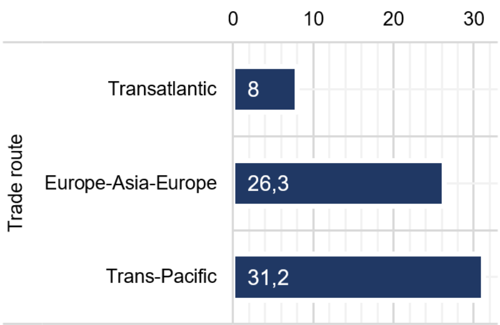

Fig. 4. Cargo flow in million TEUs through specified trade routes [25]

Northern European ports have achieved constant traffic growth, especially in 2020, with an increase of 13 % compared to 2019. The North Adriatic ports traffic increased as well, however in 2020 a decrease in throughput of about 1.7 % was recorded. The container traffic in the ports of Rijeka, Koper and Trieste has increased consistently over the five-year period [29], as presented in Table 4 and Fig. 5, respectively.

Ports	2015	2016	2017	2018	2019	2020
Antwerpen	9.370	9.891	10.032	10.830	11.676	11.970
Rotterdam	11.577	11.675	12.892	13.598	13.493	13.294
Hamburg	8.848	8.929	8.860	8.741	9.282	8.578
Total	29.795	30.495	31.784	33.169	34.451	33.842
Rijeka, Koper, Trieste, Venezia	1.995	2.114	2.319	2.506	2.546	2.505

Table 4. Total container traffic of Northern Adriatic and Northern European ports (in thousands of TEUs) [26-27, 29-30]

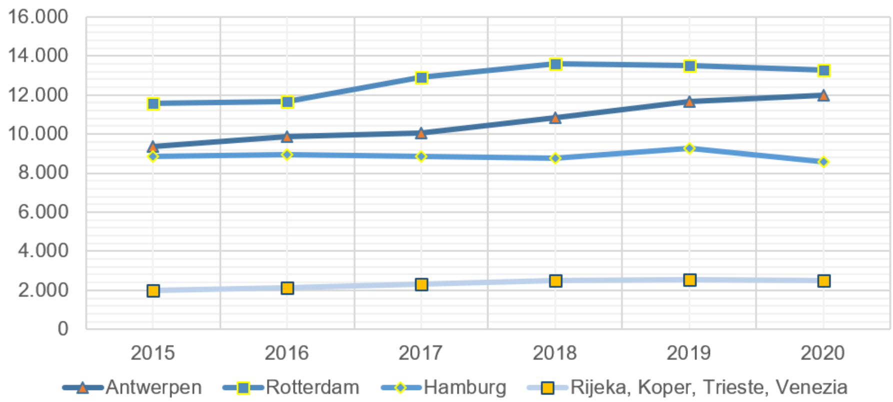

Fig. 4. Total container traffic of Northern Adriatic and Northern European ports during the period 2015/2020 [25]

Besides tendencies towards the attraction of cargoes, and respective increase in ports' systems facilities, infrastructure, and operations, and further, in transportation of goods towards final destinations, the assessment and mitigation of the environmental impact nowadays acts as one of the main trademarks of sustainable development.

2.3. Environmental aspects of port systems in the function of sustainable transportation

In maritime transportation, the strategic goal [31-32] is to reduce the 40 % of its emissions by 2050, when compared to 2005. The EC strategy provides a systematic approach to greenhouse gas emissions' reduction, consisting of measures in terms of technical, operational and market-based means. Further, the proposition is to increase the intermediate target for the greenhouse gas emission reduction for 2030 to 55 % [33]. The ecological aspect in specific terms of transport varies significantly in each individual transport mode, with actions referring to decarbonization of all transportation sectors, pollution reductions and the overall mitigation of potential environmental impact.

Considering ports and cargo terminals as natural junctions between waterfront and hinterland areas, and hubs in which different modes of transport are intertwined, the emission identification and the respective environmental impact reduction act as an indispensable element towards the effective transportation and the sole sustainability. Apart from the European Commission strategies, various and several initiatives took place towards the desired state of environmental appreciation. For instance, in [34], the role of the ports in their pollution reduction involvement is proposed through several procedures and initiatives, as presented in Table 5.

Procedure/Initiative	
Alternative energy production	Alternative fuels / low sulfur bunkering
Circular economies	Climate initiatives
Cold ironing	Efficient vessel handling
Emissions inventories	Emissions monitoring
Energy management system	Environmental plan
Environmental report	Environmental risk management
Footprint assessment	Key environmental performance indicators
Life cycle assessment	Vessel impact-related port dues / penalties and incentives

Table 5. List of procedures/initiatives defining ports' involvement in pollution reduction [34-35]

Although these initiatives refer to the wholesome pollution and waste reduction, they contain elements contributing to the transport process decarbonisation, as well as the enhancement of the transport sector environmental performance [36]. Abovementioned initiatives are considering ports as an entity in which all processes that contribute to the environmental impact are encompassed. In the proposed study, the environmental impact through transportation segment of the pollution/emissions is elaborated. Nevertheless, the intermodal port operations and respective emissions (e.g. truck/train to port terminal) have to be considered as well, in terms of environmental outcomes and/or impacts' assessment.

3 THE RESEARCH DESIGN

The previous chapters investigated the possibilities and initiatives regarding possible directions between the Far East origins and the Central European countries as final cargo destinations. The Maritime Silk Road initiative represents significant steps towards further distribution of traffic flows, each dictated by its own features.

This research segment refers to geographical features and environmental impact, latter being categorised according to their representation and significance (Table 5).

Element	Description, features and impact
Primary energy consumption	Main indicator for resource consumption
Carbon dioxide emissions	Main indicator for greenhouse effect
Greenhouse gas emissions	Greenhouse effect
Nitrogen oxide emissions	Acidification, eutrophication, eco-toxicity, human toxicity, summer smog
Sulphur dioxide emissions	Acidification, eco-toxicity, human toxicity
Non-methane hydro carbons	Human toxicity, summer smog
Exhaust particulate matter from vehicles and from energy production and provision	

Table 6. Environmental impact elements elaborated in the study. Retrieved and modified based on [37]

Considering existing container line services between Far East and Europe, two directions were selected, defined by ports of origin and destination, respectively:

1. Port of Shanghai - Port of Rotterdam (Maasvlakte), and
2. Port of Shanghai – Port of Koper.

The directions are referred as North-European (via Rotterdam) and North-Adriatic (via Koper) traffic flow, respectively. Regarding its geographical position and acting as reasonable hinterland area for both ports, the city of Munich was selected as the final destination (Fig. 6). The calculations were made for all related transportation modes, excluding air transportation. The land transportation segment was analysed from both road and rail transportation perspective, so the complete door-to-door transportation chain was defined with rail and road scenario, respectively; for each direction, two alternatives were analysed. Given the current possibilities and recent increase in block trains' capacities and intermodal rail solutions [38], the cargo shipment of 85 TEU was simulated.

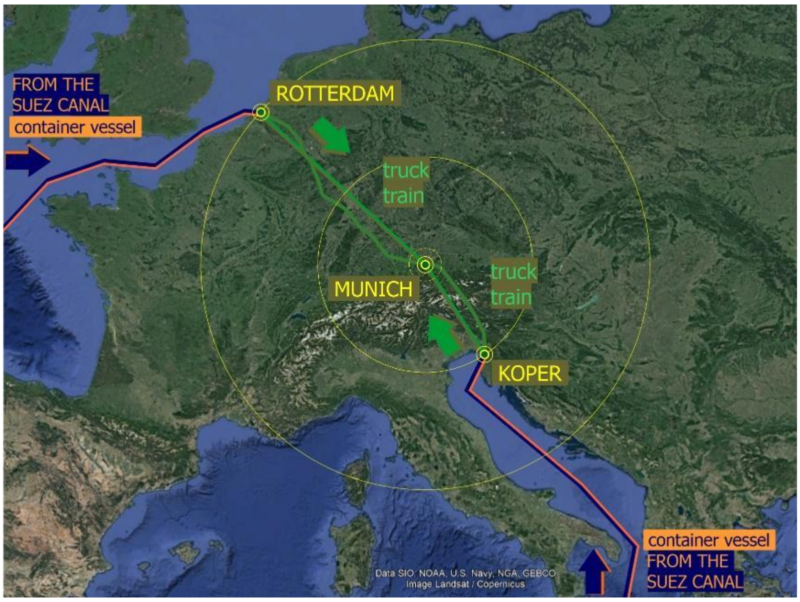

Fig. 6. Geographical presentation of simulated transportation directions with emphasis on the land transportation segment towards the final destination

The calculations of environmental parameters were conducted with *Ecological Transport Information Tool* [37], a platform serving a mean for environmental impact assessment, carbon footprint, energy consumption and greenhouse gas emissions of transport services and related sectors. The calculation of environmental impacts is conducted through several steps: route information calculation, route partition in sections, calculation of basic emissions parameters and energy consumptions, and finally, summation of all sections in order to provide with the total transport emissions. The algorithms and methodology are based on relevant information such as transport and vehicle types, propulsion and fuel types, countries' characteristics, freight types, freight allocations, and loading factors for each transport section in the door-to-door transportation chain. Details on calculation rules and respective methodology can be consulted in [37].

For each transportation scenario and respective modes, i.e. sea, road and rail, direct and indirect parameters were analysed, for two (Tank-To-Wheel, TTW and Well-To-Wheels, WTW) fuel cycle processes, namely downstream and final [39]; the environmental impact was elaborated regarding fuel emissions originated not only during the transportation of cargo, but also considering the subrange of fuel supply [40,37]. This was done to analyse and to compare the complete fuel cycle process on both directions, and to identify eventual differences and savings of the energy chain in a whole.

As presented in Table 6, the analyses comprised energy consumption (EC), emissions of carbon dioxide (CO2), greenhouse gases (measured as CO2 equivalents), nitrogen oxides (NOx), sulphur dioxide (SO2), non-methane hydro carbons (NMHC) and particulate matter (PM). Apart from environmental parameters, geographical features were calculated, to present differences in distances and savings, respectively, as follows.

4 RESULTS

The obtained results refer to separate transportation segments' distances and the total door-to-door distances for both directions. Afterwards, the environmental impact presented as emissions is presented, together with differences between modes and in a whole. Finally, the total savings are provided, represented as a result of both fuel cycle processes, and particularly, TTW consumptions.

4.1 Distances

In Table 7, the comparison of distances in nautical miles between two directions are presented, both in total and considering each of the transportation modes. For the sea transport segment, distances referring to intermodal operations (in ports/terminals) were added to the travel length.

Mode/Port	Rotterdam	Koper	Differences	Differences in %
Sea	19532.46	15848.32	3684.14	18.86
Rail	885.170	578.68	306.49	34.62
Road	845.925	507.62	338.305	39.99
Final Rail	20417.630	16427.000	3990.63	19.55
Final Road	20378.385	16355.940	4022.445	19.74

Table 7. Distances between North-European and North-Adriatic traffic direction calculated for both land transportation segments, the sea route, and total distances.

The road transportation of cargo between ports of destination and the final destination represents the greatest difference in distance (338.3 km, or 39.99 %, respectively), although the differences in favour of the North-Adriatic direction are expectedly obvious in all segments. The difference between sea transportation amounts to 3684.14 nautical miles. According to average vessel speeds of 21.5 kts, it represents a generally calculated reduction of the voyage for 7.3 days. In Fig. 7, the comparison of distances and respective savings for all simulated scenarios are graphically presented.

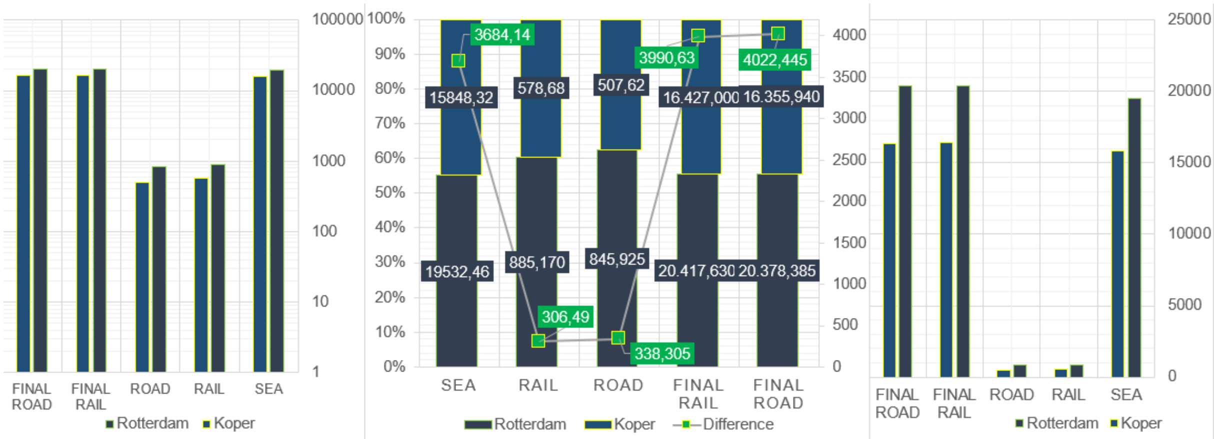

Fig. 7. Logarithmic scale (left), relative stacked bar (centre) and absolute values (right) of distances of each transportation mode and final values. On central image, the differences are presented between all elaborated transportation modes, including final travel lengths.

The natural geo-traffic flows, dictated with respective locations of ports are defining the resulting distances, or differences, respectively. Apart from distances/savings/voyage time, these features reflect also on fuel consumption and consequent emissions.

4.2 Environmental impact

The Table 8 presents the results referring to calculation of environmental parameters, considering both fuel cycle processes and all transportation segments.

Parameter	Fuel cycle	Via Rotterdam			Via Koper		
		Road	**Rail**	**Sea**	**Road**	**Rail**	**Sea**
EC (MJ)	WTW	729.995	320.831	1737.628	442.106	204.262	1372.2
	TTW	593.031	94.82	1583.576	355.728	65.85	1258.1
GHG (T)	WTW	53	17	134	32	7	106
	TTW	42	N/A	123	25	N/A	98
CO2 (T)	WTW	51	17	133	30	7	105
	TTW	42	N/A	121	25	N/A	97
SO2 (Kg)	WTW	19	21	1839	11	13	1548.8
	TTW	0.3	N/A	1707.45	0.2	N/A	1440.1
NOx (Kg)	WTW	137	23	2893	82	9	2383
	TTW	113	N/A	2831	68	N/A	2334
NMHC (Kg)	WTW	16	1	155	10	0.4	125.4
	TTW	2	N/A	104.3	1	N/A	84.79
PM (Kg)	WTW	3	3	266.5	2	1	224.25
	TTW	2	N/A	237	1	N/A	199.44

Table 8. Environmental parameters and calculated emissions for both traffic directions

As in the case of distances, the results expectedly confirm significantly less environmental impact via the North-Adriatic traffic direction. In Fig. 8, the wholesome differences between directions are presented.

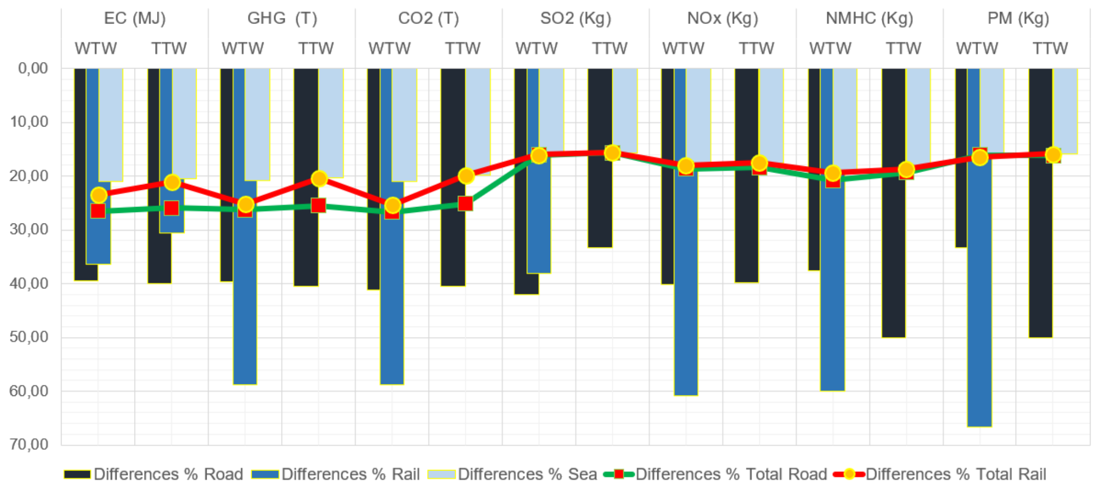

Fig. 8. Graphical presentation of calculated differences (in %) between calculated environmental parameters for the North-Europe and the North-Adriatic traffic direction for the road, rail, and sea segment. The lines represent selected total door-to-door transport chain considering road (green) and rail (red) land segment.

The Northern Adriatic direction shows lesser emissions of all elaborated parameters, referring also to both fuel cycles. In Fig. 9, the ratio of TTW and WTW fuel cycle processes for sea and road transportation is presented, as calculated for each environmental parameter, and compared between two directions.

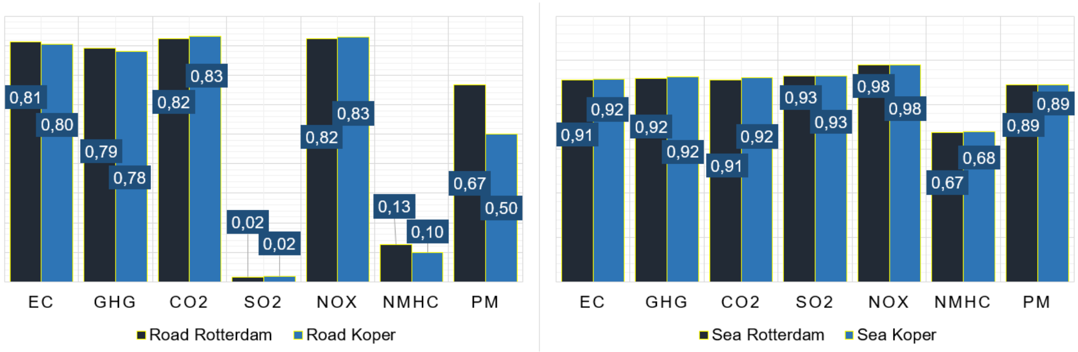

Fig. 9. The ratio of TTW and WTW fuel cycle processes for sea and road transportation segment, comparing two defined directions

The ratio was calculated as the quotient of calculated TTW and WTW environmental parameters' values. The obtained numbers indicate a difference between pure fuel usage (during cargo transportation) and the fuel usage in all processes which preceded the concrete consumption; the lesser the number, the greater difference between consumptions took place. In Fig. 10, the differences between ratios are presented for both transportation modes. Comparing the results, it can be seen that, although slightly favouring the northern (road segment) direction, the subrange of fuel supply can be considered as a not significant factor which could affect the additional emissions.

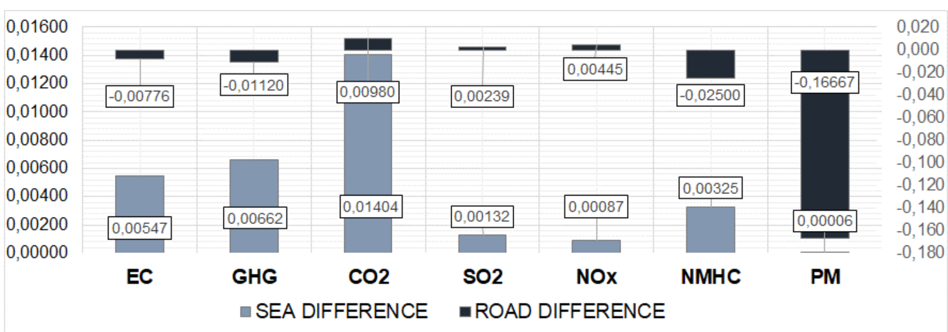

Fig. 10. Differences (%) between ratios of environmental parameters for TTW and WTW fuel cycle processes during sea and road transportation segment. The secondary axis refers to the road segment (dark bars).

The final, TTW total door-to-door transportation difference between North European and North Adriatic traffic direction is graphically presented in Fig. 10.

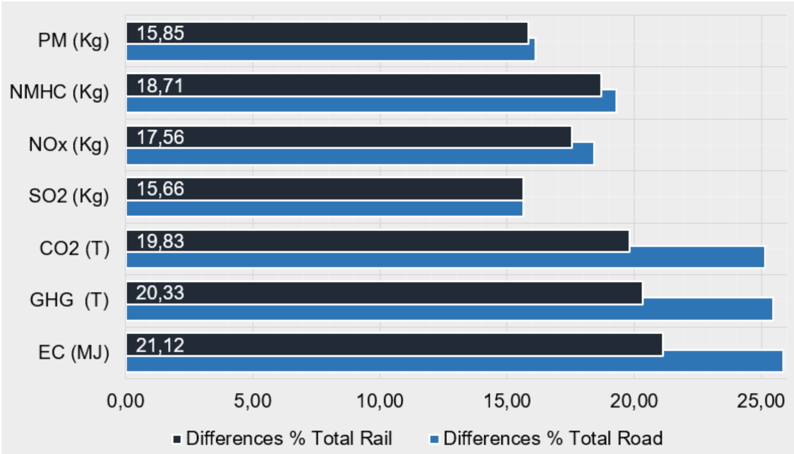

Fig. 10. Differences (%) of the total TTW sea-rail and sea-road door-to-door transportation between North European and North Adriatic traffic direction

The largest difference (21.12 %) is visible in energy consumption, which further dictates other parameters. Ranging from 15 % to 21 %, the numbers are indicating the significant reduction of the environmental impact.

5 DISCUSSION AND FINAL CONSIDERATIONS

Presented results are confirming the North Adriatic corridor as a reasonable and sustainable alternative to the dominant, Northern direction. The analyses' results support this statement in several segments. The savings in distances contribute to time spent in the transportation process, with overall amount of 19.55 % by employing rail transportation, and 19.74 % by using the road transport between the ports of call and the final destination. The voyage can be shortened between two directions for 18.86 %, or 3684.14 nautical miles, respectively. Further, considering the elaborated hinterland, for the land transportation segment the results are showing not less important reduction of transportation time, being 34.62 % for rail, and 39.99 % for road, respectively. The calculated environmental parameters during transportation of goods are also contributing to previously described sustainable initiatives and global tendencies towards de-carbonization and environmental impact reduction.

The proposed study justifies the redirection. However, apart from natural geo-traffic flows, other important factors are directly and indirectly affecting this potential process, such as economic potential of the area, development of transportation technologies, the modernization level of the transportation infrastructure and superstructure, and provision of technological, organisational and economic services.

In terms of ports' and terminals' operational, sea features, the North Adriatic ports are more limited by vessels draught than the Northern European ports, meaning the capacities of container vessels are dictated with this feature. Also, although connected with European transport corridors, the current development of the land transportation infrastructure in the Adriatic area delegates further feasibilities. These external factors were not a subject of the proposed research; however, they should be considered towards further, and more comprehensive studies.

Integration of Northern Adriatic ports represents the sound example of joint actions and the proper coupling of developing the environmental preservation, besides its primary roles, being door-to-door transportation hubs. In order to achieve this possibility, several factors have to be considered further, ranging from geo political aspects, new technologies, infrastructure, and climate change.

6 CONCLUSIONS AND PERSPECTIVES

One of the aims of the proposed study was to highlight sea routes of great importance for the development of Central European area. Far East - Central Europe connection via the North Adriatic corridor shows significant advantages when compared to the North European direction, in terms of distances and time (and costs) savings, and environmental impact reductions. The eventual (probably partial) redirection process keeps pace with tendencies towards global sustainability and greener transport initiatives.

The ports of Northern Europe have much higher total and container volumes compared to the ports of the Northern Adriatic. A greater flow of cargo through these ports would lead to the development of ports, infrastructural development of connections with the hinterland and the development of the Northern Adriatic region itself.

The connection with the hinterland of Northern Adriatic ports attracts the markets of the Central European countries. Apart from Croatia, Italy and Slovenia, the markets of Central Europe are countries that do not have direct access to the sea. The strategic goal is to continue to attract these markets to realise their foreign trade with the Far East through the Adriatic ports. One cannot expect that the complete cargo will be redirected, because this is dictated with other factors, analyses and evaluation of which remain a matter for further work. The redirection process may find its way on the micro-level, by redirecting certain amount of cargoes, and at the same time contributing to sustainable transportation.

REFERENCES

1. Meriam-Webster, A. *Webster's new collegiate dictionary (WNCD)*. Springfield: Merriam-Webste, 1977.
2. Lang, A.S.; Wohl, M. Scientific research in the field of transportation engineering. *Traffic Quarterly*. 1959. no. 13, p. 207-220.
3. Arctic Monitoring and Assessment Programme (AMAP). *Arctic climate issues 2011: changes in Arctic snow, water, ice and permafrost. SWIPA 2011 Overview Report* [online]. Oslo: AMAP, 2012. ISBN 9788279710738. [Accessed: 2 June 2022]. Available at: <https://www.amap.no/documents/doc/arctic-climate-issues-2011-changes-in-arctic-snow-water-ice-and-permafrost/129>.
4. Lee, S.W.; Song, J.M. Economic possibilities of shipping through Northern Sea route. *The Asian Journal of Shipping and Logistics* [online]. Korea : Korean Association of Shipping and Logistics, 2014, vol. 30, no. 3, p. 415–430. [Accessed: 3 June 2022]. Available at: <https://doi.org/10.1016/j.ajsl.2014.12.009>.
5. Aksenov, Y. et al. On the future navigability of Arctic sea routes: high-resolution projections of the Arctic Ocean and sea ice. *Marine Policy* [online]. Amsterdam : Elsevier Science. 2017, no. 75, p. 300–317. [Accessed: 3 June 2022]. Available at:< https://www.sciencedirect.com/science/article/pii/S0308597X16000038>.
6. Melia, N.; Haines, K.; Hawkins, E. *Future of the sea: implications from opening Arctic Sea routes* [online]. London: Government Office for Science, 2017. [Accessed: 3 June 2022]. Available at: <https://www.gov.uk/government/publications/future-of-the-sea-implications-from-opening-arctic-sea-routes>.
7. Lee, T.; Kim, H.J. Barriers of voyaging on the Northern Sea route: a perspective from shipping companies. *Marine Policy* [online]. Amsterdam : Elsevier Science , 2015, vol. 62, p. 264–270. [Accessed: 3 June 2022]. Available at: <https://www.sciencedirect.com/science/article/abs/pii/S0308597X15002572> Available at: https://www.researchgate.net/publication/283659547_Barriers_of_voyaging_on_the_Northern_Sea_Route_A_perspective_from_shipping_Companies>.
8. SRM; Intensa Sanpaolo. *The Arctic route: climate change impact, maritime and economic scenario, geo-strategic analysis and perspectives* [online]. Marina RIPOLI, 2020. [Accessed 14 February 2022]. Available at:<https://www.assoporti.it/media/6847/arctic-route-2020-isp-srm.pdf>.
9. Kos, S.; Vilke, S.; Brčić, D. Redirection of the world traffic flow Far East - Europe via the Adriatic Sea. *Athens Journal of Technology and Engineering* [online]. 2017, vol. 4. no. 3, p. 229-245. eISSN 2241-8237. [Accessed: 3 June 2022]. Available at: <https://www.athensjournals.gr/ajte/past/v4i3>.
10. Vilke, S.; Brčić, D.; Kos, S. Northern and Southern European traffic flow land segment analysis as part of the redirection justification. *TransNav: The International Journal on Marine*

Navigation and Safety of Sea Transportation [online]. Poland: Faculty of Navigation Gdynia Maritime University, 2017, vol. 11, no. 4, p. 673–679. eISSN 2083-6481. [Accessed: 7 June 2022]. Available at: <http://doi:10.12716/1001.11.04.14>.

11. Poletan Jugović, T.; Kolanović, I.; Šantić, L. World maritime cargo flows. *Naše more* [online]. Dubrovnik : Universtiy of Dubrovnik, 2010, vol. 57, no. 3-4, p. 103-112. ISSN 1848-6320. [Accessed: 3 June 2022]. Available at: < https://hrcak.srce.hr/en/clanak/89772 >.
12. Hlača, B.; Rudić, D.; Gržin E. Container traffic on the Far East: North or South Europe route. *Zbornik Veleučilišta u Rijeci* [online]. Rijeka: Veleučilište u Rijeci - Polytechnic of Rijeka, 2014, vol. 2, no. 1, p. 235–254. eISSN 1849-1723 [Accessed: 7 June 2022]. Available at: <https://hrcak.srce.hr/en/clanak/190408>.
13. Rudić B.; Gržin, E. The development of containerization in the world and the analysis of container traffic in the Port of Rijeka. *Zbornik Veleučilišta u Rijeci*. [online]. Rijeka: Veleučilište u Rijeci - Polytechnic of Rijeka. 2020, vol. 8, no. 1, p. 427–442. eISSN 1849-1723 [Accessed: 7 June 2022]. Available at: <https://hrcak.srce.hr/en/clanak/348590>.
14. Trupac, I. More containers through investments and new transport services-case study of the Port of Koper. *Pomorstvo* [online]. Rijeka: Pomorski fakultet u Rijeci, 2012, vol. 26, no. 1, p. 181–189. eISSN 1846-8438 [Accessed: 7 June 2022]. Available at: <https://hrcak.srce.hr/en/clanak/124289>.
15. CMA CGM. Phoenician Express. In: *Better ways CMA CGM* [online]. CMA CGM group, 2021. [Accessed 13 February 2022]. Available at: <https://www.cma-cgm.com/products-services/line-services/flyer/BEX2>.
16. Ports.com. Sea route & distance. In: *Ports.com* [online]. Ports.com, 2010-2022. [Accessed 8 February 2022]. Available at: <http://ports.com/sea-route/>.
17. Chan, M.H.T. The belt and road initiative – the new silk road: a research agenda. *Journal of Contemporary East Asia Studies* [online]. 2018, vol. 7, no. 2, p. 104-123. eISSN 2476-1036 [Accessed: 7 June 2022]. Available at: <https://doi.org/10.1080/24761028.2019.1580407>.
18. Koboević, Ž.; Kurtela, Ž.; Vujičić, S. The maritime silk road and China's belt and road initiative. *Naše more* [online]. Dubrovnik : Universtiy of Dubrovnik, 2018, vol. 65, no. 2, p. 113–122. ISSN 1848-6320. [Accessed: 7 June 2022]. Available at: <https://hrcak.srce.hr/en/clanak/295664>.
19. [Tamluk]. In: *Jump2spot* [online]. Jamp2spot, 2012. [Accessed 5 January 2022]. Available at: <http://www.jump2spot.com/Tamluk>.
20. Bínová, H.; Jurkovič, M. European transport corridors and North Adriatic ports. *Transport and Communications* [online]. Žilina: University of Zilina, 2015, vol. 3, no. 2, p. 1–7. [Accessed: 7 June 2022]. Available at: <https://doi.org/10.26552/tac.C.2015.2.1> Available at: <http://drepo.uniza.sk/handle/hdluniza/304>.
21. Republika Hrvastska, Ministarstvo mora, prometa i infrastructure. EU prometni koridori i TEN-T. In: *Republika Hrvastska, Ministarstvo mora, prometa i infrastructure* [online]. [Accessed 8 February 2022]. Available at: <https://promet-eufondovi.hr/eu-prometni-koridori-i-ten-t/>.
22. Vilke, S.; Šantić, L; Glad, M. Redefining of the Rijeka Railway Junction. *Promet: Traffic & Transportation* [online]. Vukelićeva: Fakultet prometnih znanosti Sveučilišta u Zagrebu, 2011, vol. 23, no. 6, p. 443–451.eISSN 1848-4069. [Accessed: 7 June 2022]. Available at: <https://hrcak.srce.hr/82065>.
23. Twrdy, E.; Batista, M.; Zanne, M. Northern Adriatic port system: competition and collaboration among container terminals. In: Martínez de Osés, F. X.; Castells i Sanabra, M. (eds.). *7th International Conference On Maritime Transport: technological, innovation and research: Maritme Transport '16.* [online]. Barcelona: Oficina de Publicacions Acadèmiques Digitals de la UPC, 2016. p. 545-554. ISBN 9788498805918. [Accessed: 7 June 2022]. Available at: <http://hdl.handle.net/2117/89047>.
24. European Commission. Top 20 ports: gross weight of goods handled in each port, by type of cargo (main ports). In: *Eurostat* [online]. European Commission, 6 December 2021. [Accessed 8

February 2022]. Available at: <https://ec.europa.eu/eurostat/databrowser/view/mar_mg_am_pwhc/default/table?lang=en>.

25. Port of Rijeta Authority. Statistika prometa. In: *Port of Rijeta Authority* [online]. Rijeta: Port Authority, [2022]. [Accessed 8 February 2022]. Available at: <https://www.portauthority.hr/statistike-i-tarife/> [in Croatian].
26. Luka Koper. Statistika pretovora. In: *Luka Koper Port of Koper* [online]. Koper: Luka Koper d.d., 2022. [Accessed 8 February 2022]. Available at: <https://www.luka-kp.si/aktualno/statistika-pretovora/> [in Slovenian].
27. Statista. Estimated containerized cargo flows on major container trade routes in 2021, by trade route (in million TEUs). In: *Statista* [online]. Statista, [2021]. [Accessed 14 February 2022]. Available at: <https://www.statista.com/statistics/253988/estimated-containerized-cargo-flows-on-major-container-trade-routes/>.
28. European Commission. Gross weight of goods transported to/from main ports: Italy. In: *Eurostat* [online]. European Commission, 2021. [Accessed 8 February 2022]. Available at: <https://ec.europa.eu/eurostat/databrowser/view/mar_go_am_it/default/table?lang=en>.
29. European Commission. Top 5 ports for containers: gross weight of goods in containers handled in each port. In: *Eurostat* [online]. European Commission, 2022. [Accessed 8 February 2022]. Available at: <https://ec.europa.eu/eurostat/databrowser/view/mar_qg_qm_pwhc/default/table?lang=en>.
30. European Commission. GDP deflator. In: *Eurostat* [online]. European Commission, 2022. [Accessed 10 January 2022]. Available at: <https://ec.europa.eu/eurostat/databrowser/view/teina110/default/table?lang=en>.
31. European Commission. *A clean planet for all: a European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy* [online]. Brussels: EC, 28.11.2018. [Accessed 7 June 2022]. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:773:FIN>.
32. European Commission. *Strategic goals and recommendations for the EU's maritime transport policy until 2018* [online]. Brussels: EC, 21 January 2009, COM(2009) 8 final. [Accessed 7 June 2022]. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52009DC0008>.
33. European Commission. *Sustainable and Smart Mobility Strategy: putting European transport on track for the future* [online]. Brussels: EC, 9 December 2020, COM/2020/789 final. [Accessed 7 June 2022]. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789&qid=165460131661>
34. Sirotić, M.; Žuškin, S.; Rudan, I.; Stocchetti, A. methodology for the sustainable development of the Italy-Croatia cross-border area: sustainable and multimodal/cross-border passenger services. *Sustainability* [online]. 2021, vol. 13, no. 11895. eISSN 2071-1050 [Accessed 7 June 2022]. Available at: <https://doi.org/10.3390/su132111895>.
35. Interreg Italy-Croatia. *Maritime and multimodal sustainable passenger transport and services (MIMOSA)* [online]. Rijeka: University of Rijeka. Faculty of Maritime Studies Rijeka. [Accessed 5 January 2022]. Available at: <https://edu.pfri.hr/mimosa/>.
36. European Commission. Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure. In: *Official Journal of the European Union* [online]. 28 October 2014, L. 307/1. [Accessed 8 June 2022]. Available at: <https://eur-lex.europa.eu/eli/dir/2014/94/oj>.
37. Anthes, R., et al. *Eco TransIT World: methodology and data update* [online]. Version 2.0. Hannover: Ingenieurgesellschaft fur Verkehrs- und Eisenbahnwesen mbH, 31 May 2021. [Accessed 11 January 2022]. Available at: <https://www.ecotransit.org/wordpress/wp-content/uploads/20210531_Methodology_Report_EcoTransIT_World.pdf>.

38. CMA CGM. CMA CGM to introduce its Duisburg intermodal rail solutions via South Corridor. In: *Better ways CMA CGM* [online]. CMA CGM group, 19 November 2021. [Accessed 13 February 2022]. Available at: <https://www.cma-cgm.com/news/3959/cma-cgm-to-introduce-its-duisburg-intermodal-rail-solutions-via-south-corridor>.
39. TIAX LLC.; California Energy Commission. *Full fuel cycle assessment: well-to-wheels energy inputs, emissions, and water impacts : consultant report* [online]. Cupertino: Tiax LLC. Revised 2007, CEC-600-2007-004-REV. [Accessed 9 June 2022]. Available at: <https://efiling.energy.ca.gov/GetDocument.aspx?tn=41758>.
40. Volkswagen AG. T is for Tank-To-Wheel (TTW). In: *Volkswagen Aktiengesellschaft* [online]. Berlin: Volkswagen AG, 2022. [Accessed 26 February 2022]. Available at: <https://www.volkswagenag.com/en/group/the-a-to-z-of-e-mobility/t-is-for-tank-to-wheel.html>.