THE IMPACT OF THE CONTAINER THROUGHPUT OF THE ADRIATIC GATE CONTAINER TERMINAL AT THE PORT OF RIJEKA ON AIR QUALITY ENVIRONMENTAL PARAMETERS[1]

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Abstract

In this paper, the authors emphasize the increase in air pollution in the eastern part of the city of Rijeka caused by the increase of the container throughput of the container terminal at the Port of Rijeka (Adriatic Gate Container Terminal), i.e., the increase in the number of vessel arrivals, the increase in the number of trucks in arrivals/departures related to road deliver/dispatch of containers.

Since the Adriatic Sea is the deepest part recessed in the European mainland, it is logical that the northern Adriatic Sea provides the Central European countries the closest access to world seas through the Gulf of Trieste and the Gulf of Rijeka. The natural advantage of the Port of Rijeka is the fact that the Dinaric Mountain barrier is the lowest and narrowest on the transport route through the northern Adriatic Sea. The North Adriatic traffic flow is the shortest natural thus the most economical way Europe relates to the Mediterranean and, by sailing through the Suez Canal, with most of the countries in Asia, Africa and Australia.

Important transportation links from landlocked Central European countries to seaports on the Adriatic coast, i.e., the Port of Rijeka, intersect on the territory of Croatia, Slovenia and Italy with other important traffic flows which move from Western and Central Europe to South-eastern Europe and the Middle East. Considering Northern and Western European ports, sea distance from Far East ports and Northern Adriatic ports, i.e., the Port of Rijeka, is approximately 2 000 nautical miles shorter, resulting in a shorter voyage time up to ten days. As for land cargo traffic directions, main Central European industrial and commercial centres are closer to the North Adriatic region by 400-600 km.

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This paper presents the geographical and traffic characteristics of the Port of Rijeka, analyzes the total container throughput and land transport to/from the Adriatic Gate Container Terminal at the Port of Rijeka. The air quality at the measuring station Rijeka 2 was also analyzed, where the parameters in five years were analyzed; nitrogen dioxide, sulfur dioxide, particulate matter (<10µm), carbon monoxide, particulate matter (<2.5µm) and ozone.

This paper aims to interpret the possible dependence between the increase in container throughput of the Port of Rijeka and air quality concerning the increased traffic of trucks, but also the port activities themselves. The expected results of this paper are manifested through an increase in container throughput in the past five years, increased flow of ships in the Port of Rijeka, a high share of shipping/delivery of containers by road transport and an increase in certain environmental parameters.

Keywords: air quality parameters, container terminal, environmental parameters, port of Rijeka.

1. INTRODUCTION

The port of Rijeka has an extremely favourable geographical and transport position, gravitating towards the lands of Central Europe. As marked on Kvarner Bay, it is the backbone of the sea and land transport route as part of the Mediterranean transport corridor. This corridor connects the Danube region and the Adriatic Sea, and is also the link between Central European countries, the Adriatic Sea and the Mediterranean Sea (Vilke, Šantić and Glad, 2011).

The container terminal Adriatic Gate Container Terminal, where container handling takes place between the sea and land sides of the Port of Rijeka, has a great impact on the increase of rail and road traffic in the city of Rijeka. In 2020, a record number of 344 091 TEU were loaded on the Adriatic Gate Container Terminal (Port of Rijeka Authority, 2021). The increased amount of shipping traffic not only brings profits to the port and the city, but also negatively affects the air quality of the area by releasing an increased number of pollutants into the atmosphere. A similar issue was highlighted in (Anastasopolos et al., 2021) where Canadian port cities further emphasize the impact of ships and fuel quality on air pollution. Given the problems in some Asian and European ports, new tools are being developed that are used to encourage the development of "green" ports in the functional activities of port operations (Lam and Notteboom, 2014).

Air quality monitoring in the territory of the City of Rijeka and Primorsko-goranska County is measured at 16 monitoring stations. The largest number of stations is located in the industrial part of the city, while the remaining number of stations is located in congested places or in areas where waste is disposed of and recycling is carried out. The results of air pollution measurements in 2018 include most of Primorsko-goranska County in the 1st category of air quality, which means clean air or negligible pollution (Project study – Connected Traffic, 2020).

2. GEOGRAPHICAL AND TRANSPORT ASPECTS OF THE PORT OF RIJEKA

Since Adriatic Sea is the lowest point on the European continent, it follows that for Central European countries North Adriatic provides the shortest access to the world's sea through the Gulf of Trieste and Rijeka. North Adriatic ports are the main link of the southern European traffic flow, the shortest natural direction connecting Europe with Asia, Africa and Australia (Vilke, Brčić and Kos, 2017) . The northern Adriatic traffic flow connects two economically complementary worlds, the industrially developed countries of Western Europe and the Asian and African developing countries. In the narrower area of Central European there is a significant existing and possible potential economic and demographic market that could use the North Adriatic traffic flow as an optimal route for the flow of goods from the Mediterranean and the rest of the world.

Table 1. Sea distances (in nautical miles) between ports of Rijeka, and Hamburg, and significant global ports

Port	*Rijeka*	*Hamburg*
Port Said	1 254	3 551
Bombay	4 315	6 620
Shanghai	8 555	10 855
New York	4 785	3 535
Singapore	6 275	8 585
Hong Kong	7 734	10 029

Table 2. Railway distance (in kilometers) of the Northern Adriatic and North European ports to certain Central European economic destinations

Railway	*Rijeka*	*Hamburg*	*Rostock*
Budapest	592	1406	1166
Bratislava	602	1022	980
Prague	806	686	644
Vienna	580	990	984
Linz	557	911	923
Munich	563	777	876

Source: (Vilke, Brčic and Kos, 2017)

The sea distance from the ports of the Far East and Northern Adriatic is about 2,000 nautical miles shorter than from the ports of the North and Western European, resulting in a shorter voyage time of up to ten days. As far as land transport directions are concerned, the main Central European trade centres are closer to the North Adriatic region by 400-600 km (Vilke, Brčic and Kos, 2017).

3. RAILWAY AND ROAD TRAFFIC CONNECTING THE AGCT WITH THE HINTERLAND

The Adriatic Gate Container Terminal is located in the eastern part of the city of Rijeka and, together with other terminals in the vicinity, forms the backbone of the port handling of the Port of Rijeka. At the terminal with a depth of 14.88 meters, it is possible to accept Post-Panamax vessels in the size of two berths, which together exceed a length of 600 meters. On a total area of 17 hectares with 2 Panamax container cranes, 2 Post-Panamax cranes, 6 RTG storage handling gantry cranes and 2 RMG rail handling gantry cranes, total annual handling of 600 000 TEU can be achieved. Since 2011, International Container Terminal Services Inc. has taken over the concession over the terminal for the next thirty years to secure an advantage in world trade over other North Adriatic ports (Adriatic Gate Container Terminal, 2021).

Figure 1. Adriatic Gate Container Terminal Rijeka (2021)
Source: (Adriatic Gate Container Terminal, 2021)

In the last eight years, the share of rail freight at the container terminal has doubled, which is a shining indicator of the application of Directive 2009/33/ EC of the European Parliament and the Council of 23 April 2009 on the promotion of clean and energy-efficient vehicles in road transport (European Parliament and Council of the European Union, 2009). The Adriatic Gate Container Terminal could see a further increase in rail capacity in 2020 thanks to the development of a new terminal intermodal facility, the operation of two additional long-range gantry laptops and the commissioning of Ranch Tunnel Pećine.

The data from Table 3 clearly show the share of land transport for the last six years in the container transport of the Port of Rijeka. According to the data below, in the period from 2015 to 2020, a period of a positive trend in the growth of port transhipment and road and rail transport was observed.

Table 3. The share of land transport in container transhipment of the Port of Rijeka

Year	*Port Transhipment (TEU)*	*Road transport (TEU)*	*Railway transport (TEU)*	*Lorries %*	*Wagons %*
2015	161.883	124.725	37.158	77.05	23
2016	177.401	132.984	44.417	74.96	25
2017	210.377	147.173	63.204	69.96	30
2018	227.375	162.422	64.953	71.43	28.6
2019	271.817	168.643	103.174	62.04	38
2020	344.091	176.746	126.880	58.3	41.7

Source: Created by authors by statistical data (Adriatic Gate Container Terminal, 2021)

In the period from 2015 to 2020, road transport has increased by nearly 42%, while railway transport has increased more than three times. It should be noted that the container terminal has significantly increased its rail capacity and more than 40% of all freight is transported by rail. It appears Table 3 and Graph 1 are used for dependent variables, but there are also other variables that must be considered.

4. THE IMPACT OF CONTAINER THROUGHPUT OF THE AGCT AND RELATED LAND TRAFFIC ON AIR POLLUTION

Motor vehicles are the primary air pollutants, with road vehicles responsible for 80% of pollution. The classical air pollutants can be divided into five groups of pollutants: Sulfur compounds (produced by the combustion of fossil fuels), carbon (II) oxide (CO), nitrogen oxides (hydrocarbons), soot, particulate matter, aerosol.

Following the pollutants occurring as combustion products of motor vehicles, which are divided into pollutants whose effects have a negative impact on human health and those whose emissions have a harmful effect on the atmosphere (so-called greenhouse gasses), ecological parameters are proposed that sensors could measure (Project study – Connected Traffic, 2020).

4.1. MEASUREMENT OF ECOLOGICAL PARAMETERS AND FUNCTIONAL REQUIREMENTS FOR ECOLOGICAL SENSORS

Following the research (the CECOM project Connected traffic) carried out in the project, ecological parameters are defined, which the sensors should measure in the area of the city of Rijeka and in zones near the terminal. Furthermore, when adopting the proposal of locations for the measurement of air pollution parameters, the current state of measurement of ecological

parameters in the wider area of the city of Rijeka was considered, assuming the application of the method of direct measurement by sensors installed at fixed locations.

The main pollutants released by motor vehicles, the measurement of which would be necessary, include (Project study – Connected Traffic, 2020):

- Particulate Matter (PM 1.0, PM 2.5, PM 10) - can be primary and secondary pollutants formed from hydrocarbons, nitrogen oxides and sulfur dioxide. The exhaust system of diesel engines is a major contributor to this form of pollution.
- Volatile Organic Compounds (VOCs) - react with nitrogen oxides in the presence of sunlight to form ozone near the ground level and are the main component of smog. Exhaust gasses from vehicles most often appear in the form of toxic pollutants, namely benzene, acetaldehyde and 1.3 butadiene.
- Nitrogen Oxides (NOx) - a harmful primary pollutant that can form ozone at the ground surface or appear as particulate matter PM (secondary).
- Carbon Monoxide (CO) - a colorless, toxic gas produced by the combustion of fossil fuels such as gasoline.
- Sulfur Dioxide (SO_2) - produced when fuels containing sulfur are burned, particularly diesel. It can also react in the atmosphere to form particulate matter (PM).

  Other greenhouse gasses - the largest contributor in this group is carbon dioxide (CO_2), followed by methane (CH_4), nitrogen oxide (N_2O) and hydrofluorocarbons (HFCs).

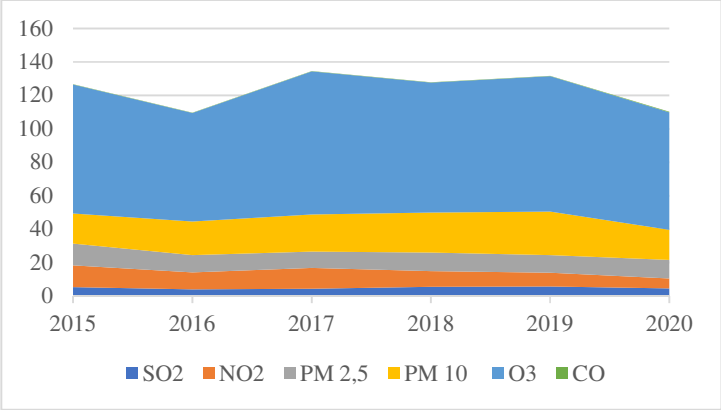
4.2. OVERVIEW OF AIR QUALITY ENVIRONMENTAL PARAMETERS AT RIJEKA 2 MONITORING STATION

The source and amount of air pollution are major factors through which it is possible to influence its reduction. Particulate Matter 2.5 (PM 2.5) and Particulate Matter 10 (PM 10) are measured as indicators of air quality, and according to European Commission, it is reported that in the EU transport is responsible for 25% of particles causing that cause air pollution in cities while industrial activities contribute 15% to pollution. Thus, although, there are significant differences between individual regions within the European Union (European Commission, 2015).

Since the port of Rijeka, i.e., Adriatic Gate Container Terminal has seen a steady increase in port transshipment (Table 3) for the past six years, analyze of parameter measurement results (SO_2,

NO_2, $PM_{2.5}$ and PM_{10}), whose excessive concentration negatively affects the quality of life of the population, has been produced in the period from 2015 and 2020.

When measuring the ecological parameters near the container terminal, the data from the station located in the immediate vicinity of the terminal, i.e. on the access road to the port of Rijeka, were considered.



Graph 1: Mean of collected parameters 2015-2020
Source: Created by authors by data (Croatian Agency for Environment and Nature, 2021)
* Note: PM10 for 2019 is the estimated value.

The data in Graph 1 show a decrease in the values of all parameters except PM10 between 2015 and 2017. The increase continued until 2020, triggered by the COVID-19 pandemic, which caused significant traffic restrictions resulting in a decrease in the value of all parameters. The estimated value (based on the increase in previous years and the available data for the months of 2019) was considered for the measurement of PM10 parameters as the instrument was in the calibration process for a certain period. However, there are other variables that must be considered (urban transport, industry, etc.) as they also affect environmental parameters.

In addition, the analysis showed that the increase in port throughput had no impact on the decrease in the quality of life of residents (in terms of air quality) in the vicinity of the terminal. Furthermore, the slight increase in container transhipment via road transport had no impact on air pollution as a significantly higher proportion of containers were allocated to rail transport.

4.3. POSSIBILITIES FOR OBTAINING MORE RELEVANT VALUES OF ENVIRONMENTAL PARAMETERS

Determining the environmental impact of port activities and the air quality of port cities is a rather complicated task, as pollution caused by port activities is mixed with land-based sources of pollution such as industrial areas, traffic, etc. (Merico *et al.*, 2021).

According to the activities carried out in the project Connected Traffic, it was found that the system for measuring ecological parameters in an urban area can have several functional levels, given the complexity of obtaining information based on the collected data. The system of measuring ecological parameters in an urban area may have several levels of function, depending on the complexity of obtaining information based on the collected data, while the method of measuring ecological parameters with appropriate equipment may be direct and indirect.
In direct measurement, sensors measure pollutant levels at predefined stations outside the pollution center and it is questionable to what extent the values obtained reflect the impact of traffic on air pollution. While such a method provides information on the measured level of pollutants at the measurement location, it does not capture the exact proportion of pollutants from motor vehicles, as the dispersion of air gasses is already present at the measurement location. A more successful method of direct measurement can be achieved by installing mobile sensors on public transportation or municipal utility vehicles. By using such method, information can be obtained on the pollution footprint and on changes or dynamics in the movement of the footprint within the target area

The indirect measurement method represents the highest level of functionality, as the subsequent analysis of the movement dynamics can provide information on the impact of traffic and its flow in terms of environmental parameters and pollution. The most relevant values of ecological parameters can be obtained by sensors placed at the source of pollution and computer models based on movement dynamics obtained by video analysis and virtual sensors, which will also be applied in the continuation of the research. Instead of applying sensors placed at the source of pollution, the devices will be installed at the container terminal itself or at the operating shore where loading and unloading of ships for pollution by ships and handling mechanization is carried out. Also, sensors will be installed at the ramp of entry and exit points for trucks at the terminal. The application of computer models will provide information on the impact of traffic and its flow in terms of ecological parameters and pollution (Project study – Connected Traffic, 2020).

In line with EU greenhouse gas emission reduction targets and increasing air pollution, it is necessary to highlight the importance of organic transport or energy efficiency in transport and to encourage projects to increase the energy efficiency of transport systems and to use vehicles with less environmental impact that make greater use of renewable energy sources and have reduced CO_2 emissions.

CONCLUSION

Road and railway infrastructure on the territory of the Republic of Croatia is very uneven, although in recent years a lot has been invested in the construction of new roads. Additional investments are needed in both existing and new infrastructure to connect the coast with the hinterland, i.e. to strengthen intermodal transport on the Rijeka transport route.

Among the many advantages for the country's economy, ports also bring certain disadvantages in terms of air quality reduction. This problem is most acute due to ships, which are the main source of pollution, along with vehicle emissions, dust and noise. Although AGCT is located near a densely populated area, according to the analysis carried out, no excessive pollution was detected that would endanger the population. However, the Port of Rijeka has the potential to attract larger amounts of cargo, so in the future it will be necessary to carry out further measurements of ecological parameters and research that will result in the sustainable development of the Port of Rijeka. The recently expanded intermodal rail terminal also has a positive effect on reducing pollution.

The Adriatic Gate Container Terminal represents an important part of the economic activities of the city of Rijeka, as the ports are considered the "gateway" to global trade. The potential for further growth of traffic in the port of Rijeka is reflected in its geographical location in the northern Adriatic with road connections with the center and Southeastern Europe. Considering the great potential of the Port of Rijeka, a further increase in container throughput followed by a higher share of shipping/delivery of containers by road transport is expected, which so far have not significantly affected the quality of life of residents living near the terminal.

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Reference list

Anastasopolos, A. T. et al. (2021) 'Air quality in Canadian port cities after regulation of low-sulphur marine fuel in the North American Emissions Control Area', Science of The Total Environment, 791, p. 147949. doi: 10.1016/J.SCITOTENV.2021.147949.

Adriatic Gate Container Terminal (2021) *Adriatic Gate Container Terminal | ICTSI*. Available at: https://www.ictsi.com/what-we-do/our-terminals/adriatic-gate-container-terminal (Accessed: 14 June 2021).

Adriatic Gate Container Terminal (2021) 'The share of land transport in container transshipment of the Port of Rijeka'. Rijeka.

Croatian Agency for Environment and Nature (2021) *Kvaliteta zraka u Republici Hrvatskoj*, *Haop*. Available at: http://iszz.azo.hr/iskzl/postaja.html?id=277 (Accessed: 13 June 2021).

European Commission, J. R. C. (2015) 'Urban air pollution: What are the main sources across the world?', *ScienceDaily*, 1. Available at: https://ec.europa.eu/jrc/en/news/what-are-main-sources-urban-air-pollution (Accessed: 12 June 2021).

European Parliament and Council of the European Union (2009) *Directive 2009/33/EC of the European Parliament of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles*, *Official Journal of the European Union*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32009L0033&from=EN (Accessed: 14 June 2021).

Krljan, T., Vilke, S.: Application of the microsimulation traffic model in Assessing congestion of the container terminal "Brajdica" access road network, International Conference of Maritime Science & Technology NAŠE MORE 2019, Dubrovnik, Croatia, 17 – 18 October 2019.

Lam, J. S. L. and Notteboom, T. (2014) 'The Greening of Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe', http://dx.doi.org/10.1080/01441647.2014.891162, 34(2), pp. 169–189. doi: 10.1080/01441647.2014.891162.

Merico, E. *et al.* (2021) 'Shipping and air quality in italian port cities: State-of-the-art analysis of available results of estimated impacts', *Atmosphere*. MDPI AG, p. 536. doi: 10.3390/atmos12050536.

Port of Rijeka Authority (2021) 'Statitistical data'. Available at: https://www.portauthority.hr/wp-content/uploads/2021/03/Priopćenje_Promet-riječke-luke-u-2020_01032021.pdf (Accessed: 13 June 2021).

Project study – Connected Traffic., C. C. (2020) *Project study – Traffic., CECOM Connected*. Rijeka.

Vilke, S., Brčic, D. and Kos, S. (2017) '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*, 11(4), pp. 673–679. doi: 10.12716/1001.11.04.14.

Vilke, S., Šantič, L. and Glad, M. (2011) 'Redefining of the Rijeka Railway Junction', *Promet - Traffic - Traffico*, 23(6), pp. 443–451. doi: 10.7307/ptt.v23i6.179.

Vilke, S., Grubišić, N. & Krljan, T. (2019) The reconstruction of the railway transport system in the service of Port of Rijeka development. U: McGarraghy, S. & Gouveia, L. (ur.)EURO 2019 - 30th European Conference on Operational Research - Conference Abstract Book.

Vilke, S., Tadić, F. (2020) Review of good practices in the introduction of traffic management systems and urban mobility, Journal of Maririme & Transportation Sciences – Pomorski zbornik, 59(1), pp.95-113. doi. 18048/2020.59.06.