European Transport \ Trasporti Europei (2023) Issue 90, Paper n° 8, ISSN 1825-3997

https://doi.org/10.48295/ET.2023.90.8

Improved port gate procedures for a better port-city relation

Marina Zanne[1*], Elen Twrdy[1]

[1] *University of Ljubljana, Faculty of Maritime Studies and Transport, Pot pomorscakov 4, 6320 Portoroz, Slovenia*

Abstract

Road congestion caused by port activities is a well-known problem that is often highlighted by local communities as one of the main negative issues related to port operations. Studies also show that road congestion can affect the competitive position of ports. The problem can be tackled in a number of ways.

The paper is divided into two parts. In the first part of the paper, the authors analyse the literature on the effectiveness of various procedures and upgrades at the port gates that can improve the gate turnaround times. The second part is a case study. In the second part of the paper, the authors quantify the current negative impacts of port-related road congestion and the benefits of introducing selected measures at the gates of the port of Koper. Isolation of single best measure is impossible due to simultaneous introduction of measures.

Keywords: port-city relation; port gate; gate procedures; gate queuing; port of Koper.

1. Introduction

The importance of maritime trade and seaports has increased with liberalization of trade. Ports now play an important role in supply chains and are major transportation hubs for national and global economic development, including for the economies of landlocked countries. The positive impacts of ports reach far into the interior of continents, while the negative impacts on local communities have become increasingly emphasized issue in recent years. Thus, the traditional view of ports as drivers of socioeconomic development in the regions where they are located (e.g., Danielis, Gregori, 2013; Jouili, 2016) is fading due to the emerging negative externalities of ports (Merk, 2013). These negative externalities include also port-related traffic and congestion in port cities. For example, the costs of road congestion due to 6% rise in freight volume in the Port of New York – New Jersey have been estimated to be between USD 0.3 and 0.8 billion per year (Berechman, 2009).

* Corresponding author: Marina Zanne (marina.zanne@fpp.uni-lj.si)

In the age of ever larger ships, ports that wanted to remain competitive had to increase their capacity. As ships grew in size, so did the amount of cargo handled each time a port is called. Besides pressure on the ports, this also put more strain on the port's land connections with the hinterland. Transportation connections to the hinterland are the responsibility of local, regional, and national governments; the port itself can only partially influence traffic flows around the port, for example, through appropriate design and capacity of port gates, optimization of gate operations, or the use of extended gates (Zanne, Twrdy, Beškovnik, 2021).

In this paper, we focus on the port of Koper, the only international cargo port in Slovenia, and analyze the effectiveness of the measures taken to improve port gate procedures and operations in order to reduce congestion on city roads.

The paper is divided into five sections. The introduction in section one is followed by a literature review on port gate procedure measures to reduce port-related traffic in urban areas. Section three describes the data and methodology used to conduct the study, while section four is the core of the paper and includes the presentation of the port of Koper and the analysis of the gate procedures optimization methods implemented by Luka Koper. Section five contains the discussion and conclusions.

2. Literature review

Ports are under pressure to develop capacity to handle increasing cargo volumes while maintaining positive relationships with local communities. Ports must develop their seaside, yardside and landside capacities synchronously or development would not yield good results. Special care must be taken when ports are located near urban areas and when port-related traffic shares roads with normal daily city traffic.

Port related road freight traffic can affect traffic flow dynamics on city roads. The ongoing growth of container ship sizes leads to high peak situations in landside container handling and thereby to a high traffic load on the port street network (Lange, et al., 2017). Delays on city roads may cause shippers to switch to competing rival ports; Wan et al. (2013) determined that the increase in urban road congestion by 1% can cause from 0.90 to almost 2.50% decrease of container throughput. On the other hand, traffic congestion reduces quality of population mobility, and causes the loss of time, higher fuel costs and increase of environmental costs. Sufficient capacity of infrastructure is a main measure that can be taken for mitigation of congestion within port–city transport system (Bernacki & Lis, 2022); however, it is not always possible. Therefore, some other measures can be considered.

Port’s landside improvement comprises gate positioning and dimensioning in regards to the port’s throughput (hard measures), but also delivery and receiving procedures and operations optimization (soft measures). We focus on the latter measures because inefficient port gate operations can reflect on the surrounding road network and cause safety and congestion problems, while also affecting service reliability (Maguire, Ivey, Golias, Lipinski, 2010).

Table 1: Possible soft measures to reduce port-related truck traffic in port cities.

Author(s)	*Research topic*
(Giuliano, O'Brien, 2007); (Maguire, et al., 2010); (Phan, Kim, 2016); (Schulte, et al., 2017); (Jin, et al., 2021)	Truck appointment system (TAS) / Vehicle Booking System (VBS) to manage port-related truck traffic and vehicle emissions due to truck idling and to improve terminal productivity initially didn't provide evidence of improvement, but this changed over time
(Motono, et al., 2016)	Simplification of entry/exit procedures and the elimination of improper documents with the compulsory pre-gate system or early registration procedures.
(Minh, Huynh, 2017); (Jin, et al., 2021)	Introduction of dedicated gates and/or lane separation (lane allocation systems) for empty trailers arriving to the port.
(Maguire, et al., 2010); (Meersman, et al., 2012); (Chao, 2017); (Neagoe, et al., 2018); (De la Peña Zarzuelo, et al., 2020)	Gate automation procedures and the use of sensors/cameras for driver identification system (DIS), license plate identification system (LPIS) or container number recognition system (CNRS); the use of radio frequency identification (RFID) for real-time monitoring, X-ray inspection area etc.
(Giuliano, O'Brien, 2007); (Maguire, et al., 2010); (Merk, 2013); (Morley, 2019);	Longer gate opening hours and peak pricing strategies

Source: Authors.

Measures listed in Table 1 are aimed at optimizing scheduling, spreading traffic throughout the day, reducing queues at the gate-in or reception areas and consequently improving environmental performance of port-related traffic, reducing needed operational staff, improving truck performance and port security etc. Usually, they provide best result if combined and supported by certain infrastructural modifications.

3. Data and methods

The creation of this paper consisted of two steps. In the first step, we reviewed the literature on measures to improve port gate procedures and operations aimed at reducing port-related congestion in urban areas as well as to address the impacts of truck traffic on traffic flow dynamics. We also reviewed studies estimating congestion costs. We used the following keywords: "port gates", "port gate procedures", "port–city relationship", "port related truck traffic", "port access roads", "truck appointment system", and "congestion costs estimation". We searched different databases, like Google Scholar, ResearchGate, ScienceDirect and JSTOR.

The second step in our research was the case study, which focused on the port of Koper. Single case studies can be debated, as they cannot provide generalized conclusions. Nevertheless, the use of case studies is widespread in port research, as this method allows a detailed investigation of the problem under study.

The main research question was formulated at the beginning of the study and was "What measures have been taken in relation to port gates performance in the port of Koper and how they reduced port-related congestion in port proximity?".

We got numerical data on port's throughput and modal split from Luka Koper annual reports. This data was accompanied with the information obtained from interviews held with the management of Luka Koper.

Annual publications of Ministry of infrastructure, Directorate of the Republic of Slovenia for infrastructure on traffic volume provide data from automatic counters on more than 950 spots on Slovenian roads, but unfortunately not on the truck traffic routs to and from port of Koper. Therefore, we used data from Luka Koper and estimated the

number of port-related trucks on the city's roads based on the port's throughput structure and land transport modal split for the period from 2008 to 2021. We related these numbers to the obtainable data on volume and structure of road traffic flows in proximity of the port of Koper and main linking road from

Congestion affects travel speed and the reliability of service and imposes the cost of travel time delay, the cost of excessive fuel consumption, and the associated cost of emissions. We approximated the extent of congestion from the information acquired in interviews in Luka Koper and by observing traffic on the main route from the highway to the port gates. Then we calculated the values of congestion costs for Slovenia from the average values of marginal congestion costs for articulated trucks and passenger cars at free flow and near capacity flow on the main urban roads in the EU, as suggested in the Updated handbook on external costs of transport by Korzhenevych et al. (2014). In the final step, we adjusted these values to Slovenia and to the appropriate year by using provided equation and data annual gross domestic product per capita ($GDPc_t$).

Marginal external costs are the additional external costs occurring due to an additional transport activity, and in short run they are linked to constant infrastructure capacity. Marginal congestion costs per vehicle kilometer (vkm) and delay cost per vkm have been used to estimate the yearly road congestion costs in the EU (Korzhenevych, et al., 2014).

4. Port of Koper

4.1 Brief description of the port of Koper

The port of Koper is relatively young port; it exists for around 65 years and in this period, it has developed to be one of the most important North Adriatic ports. The multipurpose port with specific location, bounded on two sides by urban areas and natural reserve on the third side, now spreads over around 330 ha of land and water areas.

Around 1,500 ships call to the port every year (until 2018 this number was around 2,000) and the port has total throughput of around 21 million tons of cargo. The port of Koper has small amount of transhipment activities, instead, it is an important transport node for Slovenia and large hinterland area in Central Europe. Port of Koper was selected also as one of 329 core Trans-European Transport Network (TEN-T) ports.

In the analysed period from 2008 to 2021 the volume and the structure of port's throughput have changed as can be seen in Figure 1. In 2008, the average cargo volume per ship calling to Koper was 7,207 tons, while in 2021 it raised to 13,424 tons (based on Luka Koper, 2022a). Such growth puts a strain on the port's internal organization and work safety, but also on the city's traffic and, consequently, on the environment (Zanne, et al., 2021). The structure of throughput has changed as well; the share of containers has more than doubled in the analysed period to reach almost 47% of total throughput in terms of tons in 2021 or almost 1 million TEU in absolute numbers.

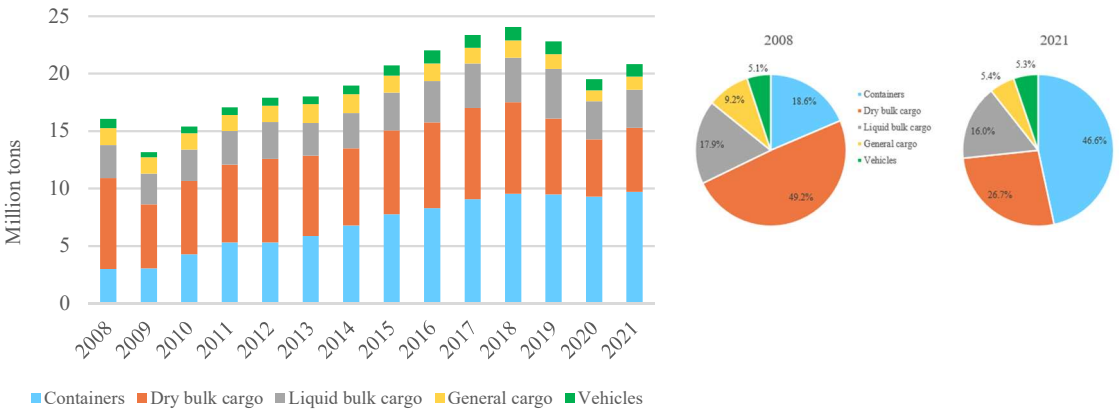

Figure 1: Volume and structure of throughput in the port of Koper.
Source: Authors, based on Luka Koper data

4.2 Port-related traffic in Koper

In 2021, almost 21,000 trains entered and exited the port of Koper, carrying a total of 276.410 wagons. This represented a 5% increase in comparison to 2020. The truck traffic increased even more. In 2021, 367.951 entered the port either loaded or unloaded; 7% more than in 2020 (Luka Koper, 2022b). Nevertheless, 58% of cargo handled in the port of Koper (transhipment excluded) was loaded on the trains, and 42% on the trucks.

Luka Koper will invest to increase the capacity and throughput of the port by 2025 to be ready to exploit the benefits of improved railway connection (second track should be in function by 2026), and in this way increase the advantages and of southern logistical route, while pursuing the goal of having at least 60% of handled quantities from the port of Koper transported by rail until the construction of new track, after which the share should increase to 70% (Luka Koper, 2022b).

Trucks contribute to transport congestion because of the lower speed in comparison to other vehicles, but in case of port-related traffic on port city roads, they can also block road lanes or even entire roads. The latest was often the case in Koper, before Luka Koper, the managing company and the only operator in port of Koper, constructed additional port gates.

Until May 2019, there was only main gate in use. The third gate was open in 2021 and is supposed to accommodate about 50% of all trucks in forthcoming years. Each of the port gates has two entry and two exit lanes, and even the lane for empty trucks; however, sometimes this is just useless due to short distances (in case of congestion there is no way to reach dedicated lane without jeopardizing traffic flow). Within the port, there is an internal container gate where pre-gate activities and procedures are done to eliminate the potential issues with the improper documents at main gates.

The Figure 2 shows the layout of the port-related routes and the distances between key points on these routes.

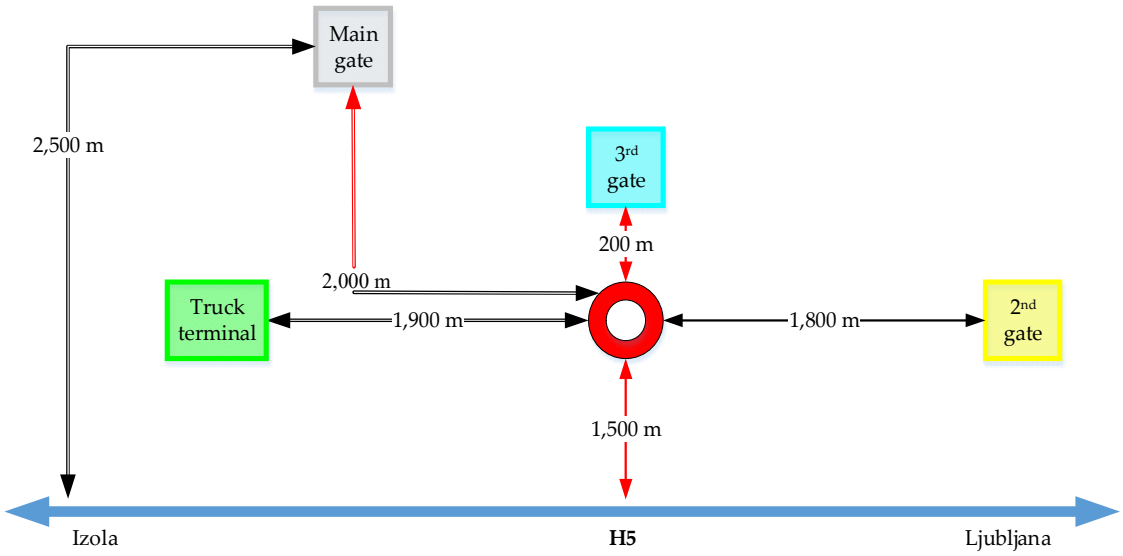

Figure 2: Schematic representation of port-related truck routes in Koper; in red potentially highly congested areas; double lanes indicate 4-lane urban road.
Source: Upgraded from (Zanne, et al., 2021).

Parallel to the construction of new port gates, Luka Koper introduced longer opening hours and the Vehicle Booking System (VBS), an online platform for making and processing truck appointments, recording truck entries into the port, and checking the validity of annual permits to enter the port. The use of VBS became mandatory by the end of November 2019. The trucks without appointment are turned away, which can cause delays at port gates and make counter effect. To reduce such situations to minimum, the users were thoroughly informed about the innovation. The conditions for entering the port are thus a confirmed booking slot that has a tolerance for entry/exit time +/- 1 hour, arrival at the agreed slot, a valid driver's permit and a prior or one-off payment of toll fee (Luka Koper, 2019).

The study from 2015 (HPC, 2015) showed that the number of trucks arriving to the port of Koper was almost constant from Monday to Friday; however, peaks were noticed in the morning between 6 and 8 a.m. and in the early afternoon, between 2 and 5 pm. The introduction of 24/7 opening hours at the main gate and the introduction of VBS flattened the arrivals throughout the day, with traffic peaks still occurring between 12 noon and 3 pm. With the port gate procedures being significantly shortened due to use of VBS and other modern technologies, the situation of extreme congestion condition with road being completely blocked in direction to the main gate (and the city) has not happened.

However, each truck must pay a toll at the truck terminal and obtain the required documents before entering the port, unless the annual fee is covered or the truck is transporting live animals, in which case the vehicle is cleaned, washed and disinfected immediately before entering the port (Luka Koper, 2019).

4.3 The estimation of port-related congestion costs on the roads of Koper

Traffic in general, but in particular truck traffic have increased greatly on Slovenian roads over the past decades, and the roads in port proximity are not an exemption. We used available data on the number of trucks serving the port in particular year (period

from 2016 to 2021), and for years in which data was not available we estimated daily number of trucks serving port of Koper in accordance to the port's throughput and average utilization level (double transactions are very rare in Koper). Following this, we estimated the volume of traffic done on the roads connecting the port of Koper, where truck traffic is mainly occurring. Estimated that total truck traffic reaches from 2.5 to 2.9 million kilometers per year (Figure 3) depending on the percentage of trucks having yearly entrance permit (paid annual fee). We approximated also traffic volume of personal cars from the data on linking roads attained from publications of Directorate of the Republic of Slovenia for infrastructure.

The estimation of yearly truck traffic volume on roads of Koper is added to average daily traffic of personal cars on these or nearby roads and then linked to average EU marginal congestion costs on main urban roads for articulated tracks and personal cars in free flow and in near capacity conditions from 2010 (Table 2).

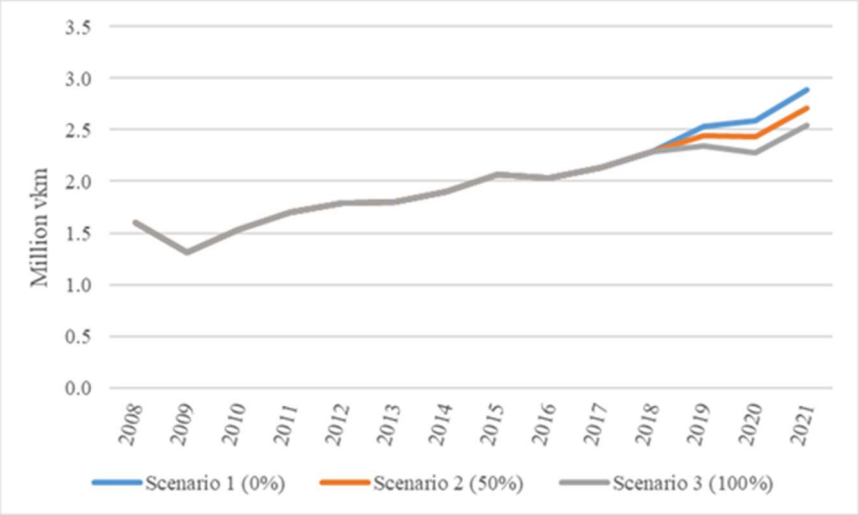

Figure 3: Estimated port-related traffic on the city roads.
Source: Authors.

Table 2: Average EU marginal congestion costs on main urban roads in 2010 [EURct/vkm].

	Free flow	*Near capacity*	*Over capacity*
Articulated truck	1.2	141.1	219.9
Personal car	0.6	48.7	75.8

Source: (Korzhenevych, et al., 2014).

Then we adjusted the provided values to Slovenia by using GDPc for particular year (*GDPc_Slovenia*$_t$) obtained from the Statistical Office of the Republic of Slovenia, by using the following equation

$$CongC\_Slovenia_t = CongC \times \frac{GDPc\_Slovenia_t}{24,400} \quad (1)$$

where *CongC* denotes congestion costs for adequate category as given in Table 2, and *CongC_Slovenia*$_t$ denotes congestion costs in Slovenia in year t.

Most of the daily traffic occurs in a 15-hour period, and most of the route being used by trucks is a four-lane road, which means that high number of trucks does not

significantly affect private car traffic in most cases. Based on observations, we defined shares with free traffic (FF) and shares with almost free traffic (NC) on Koper roads. We excluded the overcapacity situations, since they happen only occasionally, and we also excluded the congestion costs of private cars in free traffic, since they are not related to port-related traffic.

$$CongC\_trucks_t = \frac{\alpha \times FF\_trucks_t \times trucks\_km_t + \beta \times NC\_trucks_t \times trucks\_km_t}{100}$$

$$CongC\_trucks_t = \frac{\gamma \times NC\_cars_t \times cars\_km_t}{100} \quad (2)$$

The parameters α. β and γ denote percentage of traffic flows in different conditions and for different types of vehicles, and are debated and subjectively defined (α for trucks in FF, β and γ for trucks and personal cars respectively in NC conditions). *Trucks_km*$_t$ and *cars_km*$_t$ are estimated volume of traffic per year on the observed roads.

The estimated congestion costs because of port-related truck traffic from the port of Koper can be seen in Table 3.

Table 3: Estimated congestion costs because of port-related truck traffic in the port of Koper for Scenario 1.

Year	*CongC_trucks*	*CongC_cars*	*CongC_total*
2008	273,495	262,359	535,854
2009	212,035	248,386	460,421
2010	247,859	248,260	496,119
2011	279,629	252,498	532,127
2012	286,311	248,492	534,803
2013	289,426	250,670	540,096
2014	314,481	253,395	567,876
2015	354,298	276,769	631,067
2016	362,408	289,980	652,388
2017	404,483	310,008	714,491
2018	460,243	344,310	804,553
2019	365,999	205,573	571,571
2020	354,755	195,358	550,113
2021	443,749	218,999	662,748
Sum	**4,649,171**	**3,605,057**	**8,254,228**

Source: Authors.

5. Discussion and conclusions

If we apply a simple shift-share analysis on the container throughput of the North Adriatic (NA) ports, the only directly comparable cargo group for these ports, as each specializes in different segment, we can determine that the port of Koper, although being the most important container port in the region was losing traffic in past years, especially before the opening of new port gates in 2019. From the following table (Table 4) we can see the dynamics in container throughput in the NA ports. Following the idea of de Langen (2008) that the quality of service and thus the competitiveness of a port diminish when the port or its hinterland links are approaching the maximum capacity utilization

level, or maybe this shift of containers from Koper to other NA ports in 2019 can be related to congested port gates.

Luka Koper opened new gates and introduced new gate procedures pretty much simultaneously which makes the efficiency assessment of single improvement a difficult task, demanding more input data and more structured interviews in Luka Koper.

Table 4: Shift-share analysis of container throughput in NA ports in the period from 2019 (in relation to 2018) to 2021.

	2019			2020			2021		
	Exp. growth	**Shift**	**Actual growth**	**Exp. growth**	**Shift**	**Actual growth**	**Exp. growth**	**Shift**	**Actual growth**
Rijeka	6,172	71,502	77,674	-6,982	46,024	39,042	4,039	7,938	11,977
Koper	26,831	-55,978	-29,147	-21,957	7,654	-14,303	11,094	41,429	52,523
Trieste	17,012	44,870	61,882	-15,761	15,033	-728	8,075	-43,677	-35,602
Venice	17,161	-56,341	-39,180	-13,573	-50,433	-64,006	6,210	-21,460	-15,250
Ravenna	5,872	-4,054	1,818	-4,992	-18,278	-23,270	2,287	15,771	18,058

Source: Authors.

The heavy trucks driving on the roads of Koper to reach the port are often the cause of discontent among residents; however, some elements affecting the port performance are out of the reach of port authorities or companies managing the ports. Currently, the weakest point on the roads surrounding port of Koper is a small roundabout with the diameter of only around 30 meters, to which traffic from all three port gates and from highway gathers, and a single lane road from highway towards this roundabout. Especially problematic is the last open gate, the third gate, due to short distance from the roundabout, and any issues at the port gates in export direction can potentially block the road, although an external parking with 44 places is constructed nearby. This gate is intended mainly for trucks with containers following the optimization of in-port routs, but the drivers must still obtain documents from freight forwarding companies located near the main gate. This means that port gate procedures adaption didn't go hand by hand with the development of port entrances, causing additional truck flows on city roads. Otherwise, the old main entrance is currently mainly used to transport cargo from general cargo terminal and for vehicles, amounting for only around 10% of total throughput.

By the end of 2023 when the lease for existing truck terminal ends, the new, bigger one, with 322 parking spaces, should rise in the suburb of city, in between the second and third port gate. If in meantime the municipality and the state finally construct the new direct truck connection to the highway, a long time wish of Luka Koper, the port-related truck traffic would completely avoid the city roads. The construction of the link is delayed due to archaeological remains found on the site, whose excavation would cost an estimated EUR 12 million, a little more than estimated costs of congestion in analysed period alone.

References

Berechman, J. (2009) "Estimation of the full marginal costs of port related truck traffic", *Evaluation and Program Planning,* 32(4), pp. 390-396, https://doi.org/10.1016/j.evalprogplan.2009.06.008.

Bernacki, D., Lis, C. (2022) "Traffic and freight flow predictions and effects of capacity expansion in the urban–port road interface: The case of a port city in Poland", *Maritime Policy and Managementi*, https://doi.org/10.1080/03088839.2022.2068204.

Chao, S.-L. (2017) "Efficient port gate automation", *Automation and Optimization,* 74, pp. 30-31.

De la Peña Zarzuelo, I., Freire Soeane, M., Lopez Bermúdez, B. (2020) "Industry 4.0 in the port and maritime industry: A literature review", *Journal of Industrial Information Integration,* 20, https://doi.org/10.1016/j.jii.2020.100173.

de Langen, P. W. (2008) *Ensuring hinterland access; the role of port authorites,* Paris 10-11 April 2008.

Giuliano, G., O'Brien, T. (2007) "Reducing port-related truck emissions: The terminal gate appointment system at the ports of Los Angeles and Long Beach", *Transportation Research Part D Transport and Environment,* 12(7), pp. 460-472. https://doi.org/10.1016/j.trd.2007.06.004.

HPC (2015) *Rethinking container terminal management,* Hamburg: HPC Hamburg Port Consulting GmbH.

Jin, Z., Lin, X., Zang, L., Liu, W., Xiao, X. (2021) "Lane allocation optimization in container seaport gate system considering carbon emissions", *Sustainabilty, 13(7),* p. 3628, https://doi.org/10.3390/su13073628.

Korzhenevych, A. et al. (2014) *Update of the handbook on external costs of transport,* London: Ricardo-AEA.

Lange, A.-K., Schwientek, A. K., Jahn, C. (2017) "Reducing truck congestion at ports - classification and trends", In: C. Jahn, W. Kersten, C. M. Ringle (eds) *Digitalization in maritime and sustainable logistics: city logistics, port logistics and sustainable Supply chain management in the digital age*, Berlin: epubli GmbH.

Luka Koper, 2019. *Information for truckers - Vehicle Booking System (VBS).* [Online] Available at: https://www.luka-kp.si/eng/information-for-truckers [Accessed February 2021].

Luka Koper (2022a) *Cargo statistics,* [Online], Available at: https://www.luka-kp.si/en/news/cargo-statistics/, [Accessed May 2022].

Luka Koper (2022b) *Annual report 2021,* Koper: Luka Koper.

Maguire, A., Ivey, S., Golias, M. M., Lipinski, M. E. (2010) *Relieving congestion at intermodal marine container terminals: Review of tactical/operational strategies.* Arlington, Virginia, Transportation Research Forum.

Meersman, H., Voorde, E., Vanelslander, T. (2012) "Port congestion and implications to maritime logistics", In: D. Song, P. Panayides (eds) *Maritime logistics: Contemporary issues*, Bingley: Emerald.

Merk, O. (2013) *The competitveness of global port-cities: Synthesis report,* Paris: OECD.

Minh, C., Huynh, N. (2017) "Optimal desgn of container terminal gate layout", *International Journal of Shipping and Transport Logistics ,* 9(5), pp. 640-650, https://doi.org/10.1504/IJSTL.2017.086306.

Morley, H. (2019) *New gates help slash Mobile port turn times.* [Online] Available at: https://www.joc.com/port-news/us-ports/port-mobile/new-gates-help-cut-mobile-turn-times-20-percent_20191007.html, [Accessed March 2022].

Motono, I., Furuichi, M., Ninomiya, T., Suzuki S., Fuse, M. (2016) "Insightful observations on trailer queues at landside container terminal gates: What generates congestion at the gates?", *Research in Transportation Business and Management,* 19, pp. 118-131, https://doi.org/10.1016/j.rtbm.2016.04.001.

Neagoe, M., Taskhiri, M. S., Nguyen, H.-O., Turner, P. (2018) *Exploring congestion impact beyond the bulk cargo terminal gate.* Berlin, epubli GmbH.

Phan, M.-H., Kim, K. (2016) "Collaborative truck scheduling and appointments for trucking companies and container terminals", *Transportation Research Part B Methodological,* 86, pp. 37-50, https://doi.org/10.1016/j.trb.2016.01.006.

Schulte, F., Lalla-Ruiz, E., González-Ramírez, R., Voß, S. (2017) "Reducing port-related empty truck emissions: A mathematical approach for truck appointments with collaboration", *Transportation Research Part E: Logistics and Transportation Review,* 105, pp. 195-212, https://doi.org/10.1016/j.tre.2017.03.008.

Zanne, M., Twrdy, E., Beškovnik, B. (2021) "The effect of port gate location and gate procedures on the port-city relation", *Sustainability,* 13(9), pp. 1-22, https://doi.org/10.3390/su13094884.