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ORIGINAL ARTICLE

The Economic Feasibility of Port Air Emissions Reduction Measures: The Case Study of the Port of Koper

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Abstract

The importance of ports for economies worldwide is undeniable, but at the same time ports cause negative externalities. This is particularly problematic when ports are located close to urban areas. Port management must therefore try to mitigate these effects and at the same time ensure the economic prosperity of ports. This development concept is known as green growth.

In order to promote green growth, and in particular to achieve a reduction in air emissions, ports can apply equipment, energy or operational measures. The authors present the economic feasibility of different air emissions reduction measures on the case of port of Koper.

Keywords: Port, Green growth, Air emissions, Mitigation measures, Economic feasibility, Case study

JEL classification: R42, O21, O44

Introduction

Maritime transport is considered to be the most cost-effective and environmentally friendly mode of transport for the transport of large quantities of goods; nevertheless, in recent times much attention has been paid to its environmental performance. Although most of the negative environmental impacts of maritime transport occur during the voyage of ships, it is necessary to address these impacts also in ports.

Ports are complex entities that play a crucial role in the transport of goods, given that some 11 billion tonnes of freight are transported by sea every year. It is expected that international maritime trade will continue to grow at an average annual growth rate of 3.5% in the period 2019–2024 (UNCTAD, 2019). European ports are important for the European economy; they handled an estimated 4.0 billion tonnes of freight in 2017 (Eurostat, 2019). Indeed, 74% of extra-EU trade and 37% of intra-EU trade is carried by sea (Pastori, 2015). Ports directly support international trade and thus contribute to global economic growth and prosperity. Ports also create jobs; around 1.5 million people are directly employed in European ports and a similar number in supporting activities. It is therefore widely recognised that ports are engines of socio-economic development for the regions they serve (e.g. Danielis & Gregori, 2013; Jouili, 2016; Valantasis-Kanellos & Song, 2015). However, the traditionally strong relationship between ports and communities is weakening due to the emerging negative externalities of ports (Merk, 2013; Zhao et al., 2017). These are caused by the handling of goods, by ships calling at the port and by traffic serving the port hinterland (OECD, 2011), and are reflected in air emissions, water quality degradation, soil pollution, waste production, biodiversity loss, increased noise, land use impacts, traffic impacts (congestion) and other impacts such as visual impact, odour, dust and social impacts (Merk, 2013). Ports that want to

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prosper must therefore tackle economic growth and environmental protection simultaneously; the two aspects, often seen as contradictory, have now been combined to create a new paradigm of green growth.

The paper aims to assess the success of the measures to reduce air emissions in the port of Koper, the only Slovenian cargo port.

The existing studies show that port authorities that administer large ports in developed countries pay more attention to reducing air emissions and provide sustainability information to the interested public more promptly (e.g. Alamoush et al., 2020; Santos et al., 2016). Moreover, this also seems to be the case for ports located close to dense urban areas (e.g. Giuliano & Linder, 2013; Poulsen et al., 2018).

The port of Koper can be classified as a small port according to Feng and Notteboom (2013) or a medium-sized port according to the ESPO (Verhoven, 2010) when throughput is considered, although it is very important for the region it serves. The port of Koper has a particular location; it is surrounded by residential areas on two sides and a nature reserve on the third side. Port authorities generally set the port's development strategy, including green strategies, and monitor the ports' environmental performance, but there is no port authority in Slovenia. In fact, the port of Koper has a distinctive management structure; it does not fit any of the existing port management models, as it is managed and operated by a single company in which private and public capital are combined. Accordingly, private and public interests can collide.

The paper is divided into four sections, and the introduction. The first section defines the concept of the green port and describes the methods for evaluating potential measures. The second section describes the data and methods used in the paper. The third section, the core of the paper, summarizes the basic concepts on air emissions from ports and includes a presentation of the port of Koper with an evaluation of the measures taken and the current obstacles to the implementation of certain measures. The last section is devoted to the discussion and conclusions.

1 Port greening

Ports are uniquely designed social and technical organizations that have become the essential logistical links in the production, distribution and consumption chains of economies worldwide (Cetin, 2015). Ports have developed in different ways, with a combination of commercial, economic, spatial, political, social and even cultural or military influences. Consequently, ports can range from a small quay for a single ship to very large centers with many terminals and a cluster of industries and services (Bichou, 2009). Nevertheless, ports around the world, especially those in developed countries, face similar challenges; they must adapt their infrastructure and operations to changing demand while meeting increasingly stringent environmental regulations (Lee et al., 2018). As a result, the concept or philosophy of the green port has emerged.

Although there is no comprehensive or clear definition of what a green port is, ports worldwide recognize the benefits of a green port philosophy. They are implementing green port programs (Abood, 2007) to achieve a safe, efficient and environmentally sustainable port. This means that environmental problems arising from the construction and operation of ports are no longer perceived as problems but as opportunities (PIANC, 2014) and their solutions as a competitive factor of ports (Sislian et al., 2016). A green port is a port in which the port authority and port users develop and operate proactively and responsibly on the basis of an economic green growth strategy (PIANC, 2014), meaning that they must continuously attempt to strike a balance between environmental impacts and economic interests (Trozzi & Vaccaro, 2000), or, in other words, in addition to economic development, they must strive for environmental quality, ecosystem integrity, energy efficiency and the transition to renewable energies, appropriate waste management and the mitigation of climate change (OECD, 2011).

Researchers have been paying increasing attention to the negative impacts of port operations over the last 30 years (Di Vaio et al., 2019). However, the literature review shows that green ports have become an accentuated research topic since 2006 (Davarzani et al., 2016). Since then, many ports have developed Corporate Social Responsibility (CSR) strategies (Bergqvist & Egels-Zandén, 2012), including Environmental Management Systems (EMS) based on ISO 14001 or EU Eco-Management and Audit Scheme (EMAS). EMS usually consists of a collection of internal policies, assessments, plans and implementation measures (Coglianese & Nash, 2001) and procedures for staff training, monitoring, summarizing and reporting on specific environmental performance information (Sroufe, 2003). EMS can include also the energy management system or the latest can be developed as a separate energy management system (EnMS).

1.1 Selection of the green growth measures and the estimation of their results

EMS follows the "Plan-Do-Check-Act" management methodology and therefore requires scientifically sound evidence on which to base decisions, the identification of Key Performance Indicators (KPIs) or Environmental Performance Indicators (EPIs) to demonstrate success, and a suitable monitoring system to assess both the effectiveness of management and the quality of the environment itself (Wooldridge & Stojanovic, 2004). Quantification is therefore essential as it provides a baseline against which subsequent progress and performance can be measured (Merk, 2013).

In order to meet the requirements of EMS, the ports must identify and prioritize the environmental aspects. This can be done in various ways, but usually involves several steps: identifying port activities, identifying port environmental aspects, establishing the links between activities and aspects, defining criteria, determining the weighting of the criteria and finally, establishing the links between aspects and criteria (Puig et al., 2015).

The inclusion of a certain sustainability measure may increase the initial costs; however, it may lead to life cycle savings (Abood, 2007). The investments and activities must therefore be carefully analyzed. EU guidance documents suggest the use of cost-benefit analysis (CBA) in the decision-making process for investment projects, as it is a comprehensive method with standardized rules (HM Treasury, 2018). Any CBA should integrate the economic cost of air pollution, which includes health impacts, building and material damages, crop losses and impacts on ecosystems and biodiversity (EC, 2015). The results of cost-benefit analysis are usually expressed in terms of payback period (PP). PP is the period of time needed to cover the costs of an investment.

$$PP = \frac{TC}{TR} \quad (1)$$

where TC = total costs, and TR = total revenues (or benefits).

However, calculating PP ignores the time value of money, which can be overcome by using net present value.

Another option is to use the cost-effectiveness analysis (CEA), which can be applied when the benefits cannot be expressed in monetary terms. CEA is relatively easier to calculate than CBA because not all things need to be quantified in monetary terms; however, CEA does not allow comparisons between activities that produce different results. CEA results are expressed as ratios, namely the cost-effectiveness ratio (CER) or incremental cost-effectiveness ratio (ICER).

$$CER = \frac{C}{E} \qquad ICER = \frac{\Delta C}{\Delta E} \quad (2)$$

where C = cost of project or intervention, and E = effect of project or intervention.

2 Data and methods

The paper consists of a two-step research process. First, we summarized the theory of port greening and methods for selecting and evaluating port greening measures. Keywords such as "green ports", "port greening", "port sustainability", "ports' air quality", "port operations air emissions", "port air emissions mitigation measures", "energy management in ports" were considered in the ScienceDirect database and Google Scholar.

We proceeded with the case study focusing on the port of Koper and the measures taken by the managing company to reduce air emissions. Although case study methods can be perceived as controversial, especially single case studies as they cannot provide generalized assumptions (in the sense of statistical generalization), they are widely accepted in the social sciences. In fact, case study research can be used to generate or test theory with real case studies. This is especially true for ports. There are thousands of ports around the world, but it is almost impossible to find two that have the same operating conditions. Therefore, the use of the case study method, which allows for a detailed examination of the area under study, is very common in the initial analysis of ports.

The research question was formulated at the beginning of the study. The main research question was "What air reduction measures are applicable in the port of Koper and how efficient are the measures taken?".

Interviews and document review were used to obtain data that enabled a detailed analysis of the case study. Interview questions were based on the literature review and the EcoPorts self-diagnostic checklist.

3 The Port of Koper

The port of Koper started its activity in December 1958, with 135 m of quay. Since then, the port has developed into one of the most important North Adriatic ports; the port of Koper holds the leading position in container traffic in the Adriatic Sea and ranks third among Mediterranean ports in terms of car transshipment.

The port of Koper is the only Slovenian international cargo port. It is managed and operated by the joint-stock company Luka Koper. The multipurpose port has twelve specialized terminals with 3300 m of quay and 26 berths. Seventy kilometers of roads and thirty kilometers of railways connect all terminals to the public transport infrastructure. Around 2000 ships call at the port annually. In 2018, the port handled around 24 million tons of cargo and almost 1 million TEUs (see Fig. 1).

The port of Koper supplies a wide hinterland that includes Slovenia, Croatia, Austria, northern Italy, Hungary, Switzerland, southern Germany, Czech Republic, Slovakia, Serbia, and marginally some other countries. These countries have good economic potential, which could be enhanced by the movement of the "blue banana" towards the east. Moreover, the port of Koper is located on the Baltic-Adriatic corridor, which is labelled as one of the main trans-European road and rail axes. Koper (and other North Adriatic ports) represent the most convenient and environmentally friendly trade route connecting Central Europe with the Middle and Far East. Not surprisingly, Luka Koper has ambitious expansion plans. Accordingly, throughput is expected to increase.

3.1 The green management of the port of Koper

The port of Koper is designed and operated according to sustainable principles. Luka Koper manages the entire port area. This enables the implementation of an environmental protection system on all terminals and for all its activities. Luka Koper obtained ISO 14001 in 2000. In May 2006, this standard was upgraded to ISO 14001:2004, while Luka Koper obtained EMAS certification in 2010. This made it compliant with the highest environmental criteria of the time (Luka Koper, 2018). Currently, Luka Koper is adapting its environmental management system to meet the requirements of the energy efficiency standard ISO 50001. Luka Koper has prepared its EMS and has the Environmental policy, which refers to the European Sea Ports Organisation (ESPO) guidelines. It ranked noise as the main priority, followed by dredging, air quality, dust, energy consumption and relationship with the community (interview in Luka Koper).

3.2 Port air emissions reduction measures

Air emissions are only one of the negative impacts addressed by the port green growth concept. Air emissions are generally divided into two categories, greenhouse gas emissions that cause climate change and air pollutants that are harmful to the environment and human health. The latter is particularly important if the port is located near urban areas.

As can be seen from the figure below, many port and port-related activities cause air emissions and air quality degradation. The problem can be addressed in different but somewhat interrelated ways, including changes in equipment and energy consumption, as well as at the operational level (see Fig. 2).

The literature overview on the measures for air emissions mitigation from port and related activities is presented in Table 1.

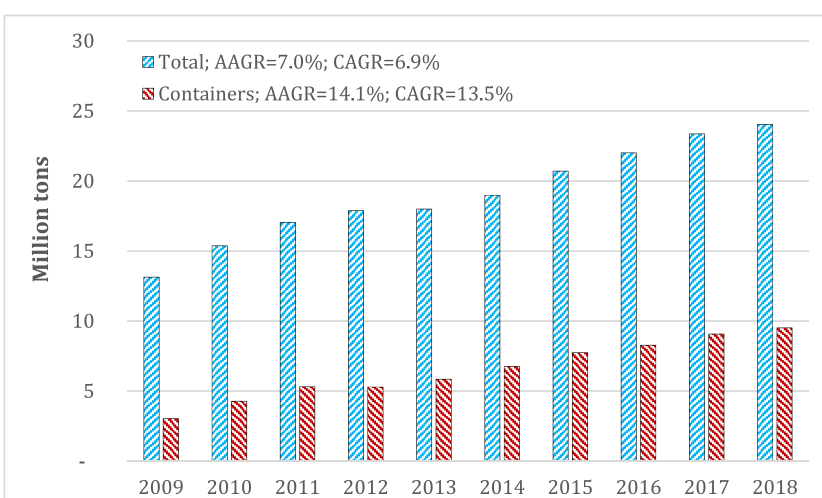


Fig. 1. Total throughput and container throughput in the port of Koper [in million tons]. Source: authors, based on Luka Koper, 2019a.

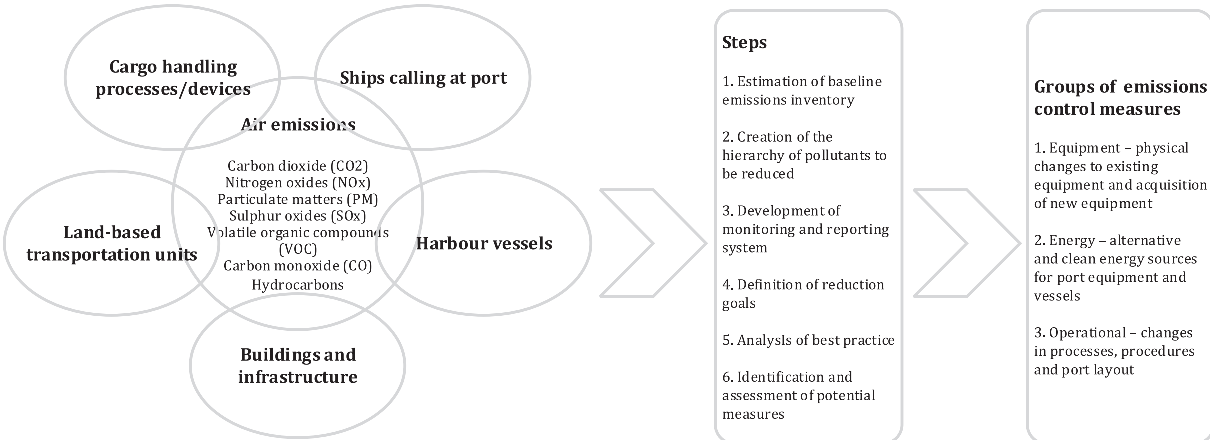


Fig. 2. The sources and elements of port air emissions, and air emissions reduction measures. Source: authors.

3.2.1 Equipment measures

Rubber-tired gantry cranes (RTGs) are the largest consumers of diesel fuel and the largest contributors to air emissions in the port of Koper. On average, an RTG consumes about 12 L of diesel per hour, and they typically operate 22 h per day, more than any other piece of equipment (for comparison, ship-to-shore (STS) container cranes operate an average of 9 h per day). Therefore, one of Luka Koper's strategic projects is the electrification of RTGs and other container terminal equipment. Currently, Luka Koper operates nine electrified STS container gantry cranes, twelve electrified RTGs (e-RTGs) and three rail-mounted gantry cranes (RMGs), which represent 23.8% of the equipment and mechanization at the container terminal.

The e-RTG costs more than a comparable diesel-powered RTG; however, the estimated direct savings are EUR 60,000 per year per e-RTG compared to diesel-powered RTGs (interview in Luka Koper). In

Table 1. Literature overview on air emission reduction measures in ports.

Author(s)	Field	Research topic/Findings
Acciaro et al., 2014; Poulsen et al. (2018)	Operational measures	Limits regarding the emissions for the road and rail vehicles operating within the port
Chen et al., 2013; Phan & Kim, 2015; Mjelde et al., 2019; Lind & Haraldson, 2016; Chang & Wang, 2012; Poulsen et al. (2018)	Operational measures/ Collaboration	Improvement of coordination and synchronization between ship and port, the optimization of the movements within the port and reduction of idle time of equipment and vehicles, provision of automated cargo-handling operations
Lee & Nam, 2017; Mjelde et al., 2019	Operational measures/Port dues	Differentiated dues in relation to the environmental performance of ships
Bergqvist & Egels-Zandén, 2012; Lam & Notteboom, 2014	Operational measures/Port dues/Modal shift	Differentiated dues in relation to selected mode of transport in hinterland
Chang & Wang, 2012; Chang et al., 2013; Linder (2018)	Operational measures	Speed reduction zones for ships
Burns, 2015; Acciaro et al., 2014; Çağatay & Lam, 2019; Lam et al., 2014; Zis et al., 2014; Chang & Wang, 2012; Winkel et al., 2016	Equipment measures Energy measures Energy consumption Energy management Carboon footprint	Modernisation and electrification of equipment, the use of autonomous vehicles and vehicles powered by liquefied natural gas (LNG), energy storage systems, alternative energy sources, on shore power supply (OPS)
Corbett et al., 2007; Chatzinikolaou et al., 2015	Health impacts	Local polluters and particles cause cardiovascular or respiratory system diseases and deaths
Peris-Mora et al., 2005; Perotto et al., 2008; Puente-Rodríguez et al., 2016; Laxe et al., 2016; Laxe et al., 2017; Puig et al. (2015)	Environmental performance indicators	Identification of a comprehensive set of KPIs and EPIs to quantify port performance and the formulation of Global Synthetic Index (SI)
Lam & Notteboom, 2014; Chen & Pak, 2017; Acciaro et al., 2014	Operational measures/ Monitoring	Input for strategies and tool for assessing progress and transparency of operation

Source: authors.

addition, e-RTG offers 95% savings in diesel consumption, up to 70% reduction in operating costs, up to 70% reduction in maintenance costs, as well as significant reduction in greenhouse gas emissions (CO2 and NOx) and noise pollution (Naicker & Allopi, 2015). Therefore, it is meaningless to calculate the payback period for this equipment alone, as the scope of the purchase is much larger. Luka Koper will continue to replace the equipment with the electric one instead of retrofitting the existing equipment with hybrid power pack, diesel fuel saver, cable reel system, or conductor rail system.

The total energy consumption of the container terminal has increased in the period from 2015 to 2018 (diesel consumption remained at approximately 3.1 million liters, while electricity consumption increased from approximately 6400 to 8700 MWh), but so has the throughput (from 790,736 to 988,501 TEUs, or from 7,741,976 to 9,520,007 tons). The better energy consumption structure and higher throughput resulted in lower consumption and a lower carbon footprint per unit handled, as shown in the Table 2.

In addition to the mobile equipment of (container) terminals, the lighting of yards and warehouses has a high share in the electricity consumption of ports. Therefore, installing an intelligent and efficient lighting system is an excellent way to reduce overall electricity consumption and, consequently, harmful emissions and light pollution. Efficient lamps, fittings and controls save money and improve working conditions (ESPO, 2013). Dolamič (2018) conducted the CBA for the installation of a new LED lighting system on one of the road sections of the port of Koper, in the garage for new vehicles, in a typical warehouse and at the container terminal. All simulations predicted cost savings between 65 and 80%, and an extra benefit in form of better and safer working conditions. About 85% of outdoor lighting within the port of Koper complied with the regulation on limits due to environmental light pollution already by the end of 2013 (Luka Koper, 2014).

Air quality is affected not only by emissions from fuel combustion, but also by particulates that rise into the air during manipulation with certain types of cargo, especially dry bulk. As residential areas and sensitive nature reserves surround the port of Koper, Luka Koper built a closed conveyor system for unloading ships at the iron ore and coal terminal and equipped the ship loader with an anti-dust telescopic pipe. They also built a system of sprinkler towers and an aluminium barrier with a height of 11 m. By spraying a special cellulose mixture on the stockpiles, they cover the coal and ore with a crust that prevents dust formation even in high winds (Luka Koper, 2019b). In addition to construction costs, there are almost no operating costs because the cellulose mixture is made from a waste product of the paper industry and the water used to clean the transport route around the terminal is collected, treated and reused. The economic result of the project is negative, but the cost-effectiveness is high as the air quality, expressed in particulate matter (PM) concentration, within the port area and its surroundings is now better than in most major cities in Slovenia.

3.2.2 Energy measures

The port of Koper is located in the North Adriatic, where the tides and waves are negligible and thus cannot be used as a source of energy. Also the wind conditions are not suitable for the installation of wind turbines, at least not such that could significantly contribute to the use of renewable sources. On the other hand, the region has many sunny days, which makes the roofs of warehouses a good option for the installation of photovoltaic systems. Two solar power plants are possible in the port of Koper. A 12 MWp plant (Mega-Watt peak) power that could be built by covering 84,000 m2 of roofs within the port (Luka Koper, 2017), and the larger one covering 700,000 m2 of open space parking lots within the port, which could produce about 115 million kWh of electricity annually and would cost about 155 million EUR (own calculation from Tavčar, 2019).

The construction of the first solar power plant is economically feasible and is planned to be done in phases; at least 1.25 MWp should be constructed by 2025 and at least 3 MWp should be in operation by

Table 2. Energy consumption at the container terminal of the port of Koper in 2015 and 2018.

	2015	2018	Index
Total energy [MWh]*	39,393	42,355	107.5
Total carbon footprint [mio kgCO2eq/year]**	11,505	12,552	109.1
Energy consumption per ton of throughput [kWh t]	5.09	4.45	87.4
Energy consumption per handled TEU [kWh/TEU]	49.82	42.85	86.0
Carbon footprint per ton of throughput [kg CO2eq/t]	1.49	1.32	88.6
Carbon footprint per handled TEU [kg CO2eq/TEU]	14.55	12.70	87.3

Note: *Energy equivalences used: $1kWh_{electricity} = 3.6$ MJ and $1l_{diesel} = 38.29$ MJ as conversion factors. **Equivalences used in carbon footprint calculation: 0.375 kgCO2eq/kWh for electricity and 0.276 kgCO2eq/kWh for diesel as used by Luka Koper.
Source: own calculation, based on Luka Koper, 2016; Luka Koper, 2019a; interview in Luka Koper.

2030. On average, the payback period is expected to be between 10 and 13 years as each rooftop project must be evaluated individually. The second project would result in a much longer payback period as it would require the installation of car roofs; however, it should be economically more feasible with the expected continued decline in the price of photovoltaic systems. The additional benefit of this project would be the protection of the new vehicles, which are one of the strategic cargoes in the port of Koper.

Once built, these power plants would make the port energy self-sufficient, even if shore power is installed. OPS would reduce emissions from ships in port, since ships' auxiliary engines must be on throughout their stay in port to provide power on board. Ships have different engine configurations; however, diesel-mechanical ships typically have 2 or 3 auxiliary engines installed, while diesel-electric ships have 4 to 6 auxiliary engines (GLMEEP, 2016). For example, a rather small container ship with a capacity of about 4000 TEU has three auxiliary engines, each with a power of 2320 kW, and each consuming 4.5 tonnes of fuel per day while in port. However, also much larger ships call to the port of Koper. From the beginning of 2020, the sulphur content in marine fuel must not exceed 0.5%, but still when burned a tonne of marine bunker produces on average 3.17 tonnes of CO2, regardless of the fuel type or engine type, $0.02 \times S$ tonnes of SO2 (where S stays for sulphur content in fuel) and 0.057–0.087 tonnes of NOx, depending on the marine engine (Psaraftis, 2008).

Nevertheless, there is currently no practical reason for the installation of OPS in the port of Koper, as only one ship calling the port is equipped with the appropriate system. The installation of OPS on all terminals in the port of Koper would require an investment of approximately EUR 60 million (interview in Luka Koper) and the installation of a costly system on board the vessels, which the shipping companies are not willing to do. Moreover, the construction of the OPS would interfere with daily port operations and could jeopardise the reliability of port services, while the required transformers would permanently hinder the movement of land cranes and terminal vehicles. Operating OPS throughout the port would hugely increase electricity demand and require a completely different system of power supply to the port; Slovenia is not ready for that either. The installation of OPS would perhaps make sense after the construction of the solar panels mentioned above.

Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure requires that at least by the end of 2025 a core network of refuelling points for liquefied natural gas (LNG) is available in seaports, not only for the refuelling of port equipment, but also for the provision of bunkering facilities for ships calling at the port (Official Journal of the EU, L 307/1, 2014). The study on the gradual introduction of LNG terminal vehicles in the port of Koper was carried out in 2016. It envisaged the acquisition of 95 land-based transport and handling units in the period from 2020 to 2030. The project is currently on hold as the port is not connected to the gas pipeline, which would require external supply by tank-trucks or boats, consequently increasing operating costs. However, as LNG becomes more and more important as an environmentally friendly solution for bunkering ships, not only for merchant vessels but also for tugboats, it might become necessary to install the LNG station in the port of Koper. At the same time, the LNG-fueled terminal equipment should be reconsidered, as the use of LNG, in addition to the economic advantages, brings many environmental benefits, such as the reduction of SO2 emissions by almost 100% and the reduction of CO2 emissions by more than 25% compared to diesel-fueled equipment. In addition, emissions of particulate matter and NOx are also reduced.

3.2.3 Operational measures

A relatively low-cost measure that can reduce energy consumption and thus emissions while maintaining operational efficiency is eco-driving and optimized routing of terminal equipment. The studies show that fuel consumption can be reduced by an average of 10–15% per year through eco-driving (Kristensen, 2009). The drivers of Luka Koper have been trained to use the equipment safely and properly and will also undergo the eco-driving training in the coming years.

Another applicable soft measure is the scheduling of truck arrivals. This is called truck scheduling system (TAS) or vehicle booking system (VBS) and can, among other things, lead to a better utilization of the (container) terminal. It is particularly beneficial when used to reduce the dwell time of reefer containers at ports, as these are large consumers of energy. Luka Koper completed the VBS in November 2019, so the results cannot yet be evaluated.

At least thirty ports in the EU apply environmental charges, meaning the environmentally friendlier ships according to the emissions ship index (ESI) or certification programmes (e.g. Green Award) pay lower port fees. The discounts can range from 0.5% to 20% (EC, 2017). While the implementation of this measure may improve the image of the port, its value is broader as it could help incentivize more sustainable development of ships by supporting the adoption of cleaner fuels in maritime transport. Luka Koper has sent the initiative to introduce an environmental charging system in the port of Koper to the Maritime Administration of Slovenia and is still waiting for an official response.

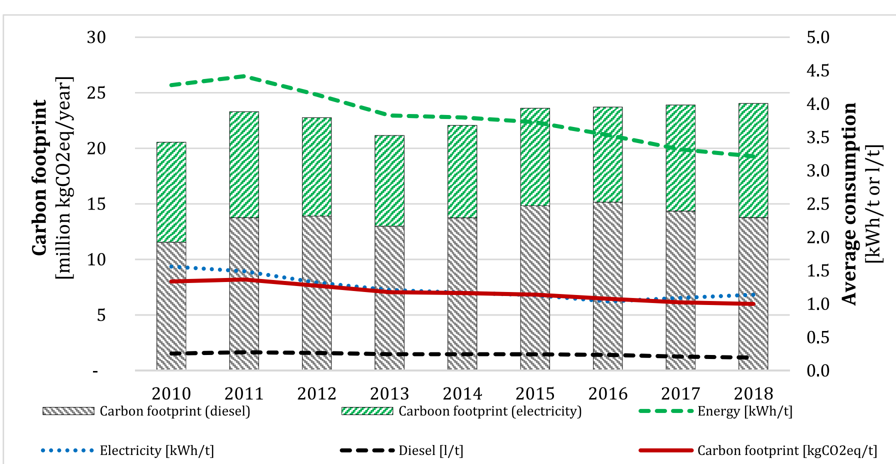
Moreover, the configuration of the terminals can lead to a change in energy consumption and improved traffic flow within the port. Luka Koper has relocated its RoRo terminal, which will result in lower mileage of the new vehicles in the port and lower emissions. In addition, most of the traffic will be handled further away from urban areas.

4 Discussion and conclusions

Ports are expected to align their performance with overall sustainability goals, i.e. deliver optimal economic and social outcomes while causing minimal environmental damage (UNCTAD, 2019). Measures taken by ports under the green port philosophy therefore become the main element of port strategies. These measures can be classified as organisational or technical-technological; however, not all measures can be taken by all ports for various reasons, but mainly because of financial resources as many can be very demanding (Olesen et al., 2012) and thus expensive. Small ports usually have lower revenue per employee, lower earnings before interest, taxes, depreciation and amortisation (EBITDA) per employee, lower return on investment, higher operating costs and higher cost of capital per unit handled than larger ports. Smaller ports have lower revenues and, consequently, fewer resources for research and development and the investments associated with improving the port's sustainability. Adequate sustainability management is therefore rarely found in smaller ports (Kuznetsov et al., 2015), but Luka Koper suggests otherwise.

The port of Koper is a small port with a limited budget, e.g. Luka Koper invested €15.8 in 2018 with EBIT of €69.7 million (Luka Koper, 2019a,b), while the Port Authority in Rotterdam made alone € 408.1 million of investments in the same year (Port of Rotterdam Authority, 2019), while the investments of private operators are not known. However, with the same environmental impacts as any other larger port (in terms of elements, not volume). Luka Koper does not escape this; on the contrary, it is not only the economic benefits and profits that exclusively guide the company's decisions, but also the environmental performance. Environmental quality and port–city relations occupy an important place in the port's strategic orientations. Luka Koper has even set up a sophisticated measurement system with real-time publication of data so that the transparency of its environmental efficiency can be monitored at any time.

Yet, as a small port facing the above-mentioned concerns, Luka Koper has to prioritise investments, even though the port is one of the 83 EU ports in the core trans European transport network (TEN-T) and thus eligible for co-financing of projects, especially those dealing with energy-saving and environmentally friendly solutions. Any investment decision requires extensive elaborates, which are per se expensive and time-consuming.



Note: We used 1kWh=3.6MJ and $1l_{diesel}$=38.29MJ as conversion factors; we used total throughput as a productivity parameter.

Fig. 3. Average energy consumption and carbon footprint from the Port of Koper. Note: We used 1 kWh = 3.6 MJ and $1l_{diesel}$ = 38.29 MJ as conversion factors; we used total throughput as a productivity parameter. Source: Authors based on Luka Koper, 2016; Luka Koper, 2019a; Luka Koper, 2019b; interview in Luka Koper.

The strategic direction of the company is to achieve high energy efficiency in all business processes carried out in the port area. As can be seen in Fig. 3, energy consumption per tonne of cargo handled decreased by more than 20% between 2009 and 2018. This is also reflected in the carbon footprint of the entire port, which fell by almost 22% over the same period.

The main objective of this paper was not to compare different ports, but to analyze the activities of Luka Koper in terms of environmental performance. We focused on the measures taken by Luka Koper to reduce air emissions from the port's core activities. The specific organizational model of Luka Koper, with the potential clash of interests between private and public ownership, motivated us to select this port because private capital typically pursues revenue maximization from available assets and demand-driven infrastructure investments, while public commitments include social responsibility and involve decision making where negative externalities are relevant, including the activities and measures to reduce air quality deterioration.

The activities taken so far by Luka Koper are in line with EU directives and the concept of sustainable development; the measures taken have contributed to reducing the carbon footprint of the port and improving air quality around the port without negatively affecting the throughput of the port. These measures are highly appreciated by local citizens, as evidenced by annual surveys.

Although the monetary valuation of air emission reduction measures is challenging, studies show that the economic benefits of many air pollution control measures exceed their costs, even when only health impacts are assessed (e.g. Holland, 2014; Sofia et al., 2020). This can be seen also on the case of the port of Koper. Some of the measures taken, such as replacement of the terminal equipment, are necessary because the equipment has a limited lifespan. Luka Koper decided to buy more expensive equipment, but equipment that is environmentally friendly and costs less to operate. On the other hand, some of the planned measures are not indispensable and require large initial investments, but are considered as long-term strategic solutions to reduce air emissions (energy measures) and ensure energy self-sufficiency of the port.

The port of Koper is not only important for the local community, but also has a greater economic impact; therefore, the state should support Luka Koper to achieve high environmental standards and also implement certain environmental measures. For example, Winkel and others (2016) claim that if all ports in Europe used electricity from OPS in 2020, an estimated €2.94 billion in health costs could be saved and an approximate reduction in carbon emissions of 800,000 tons could be achieved. These benefits are far-reaching, and the costs of installing and operating OPS should not be borne solely by ports and shipping companies. Luka Koper also cannot offer differential charges for those cargoes that use rail transport, as the rail infrastructure is inadequate and the utilization rate is close to the limit, so the alternative to road transport is not always possible. However, there are plenty of other, either operational or technological, measures to reduce air emissions, such as the reduction of the ship speed in the port aquatorium and in the vicinity of populated areas or a better synchronization between ship and port when the ship arrives in port, improvements in landside operations etc.

While this paper provides insight into Luka Koper attitudes toward environmental issues with a focus on air quality, there is still much for future research. Air quality indicators could be analysed to form models related to port activity parameters, which would support management in decision-making processes. Other elements of port sustainability or port–city relationship, such as noise, traffic congestion or health problems occurrence in the local population could also be investigated. And last but not least, environmental accomplishments of Luka Koper should be compared to ports with similar attributes but a different management model.

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