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Environmentally Friendly Cruise Seaports in Northern Europe – Onshore Power Supply

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ABSTRACT: The investment policy applied by seaport authorities has a great impact on the state of the natural environment in coastal regions. Unfortunately, in many cases, their environmental efforts are limited to the issues which are defined by the applicable legal regulations determined by International Maritime Organization, the Organization of United Nations and the European Commission etc.
However, in recent years we can observe significant improvement in this area, especially in the seaports of Northern Europe. They often decide on highly capital-intensive pro-ecological investments allowing to reduce the level of pollution emitted from cruise ships during their handling in ports, such as e. g. the opportunity of connecting vessels to the shore-side energy supply systems. Various solutions in this area are currently used in the world. The ports in Northern Europe are currently the leaders in this area. The use of such solutions is cost-intensive, but it significantly reduces the level of pollution emitted by ships into the environment, and the level of noise and vibration caused by engines. This paper aims to assess the seaports' involvement in Northern Europe in the preparation of seaport infrastructure enabling cruise ships to be connected to the onshore power supply systems. The article contains the results of surveys conducted with the use of two methods to adjust the research technique to the respondents' needs, i.e. CASI (Computer-Assisted Self Interviewing) and EMS (Electronic Mail Survey). The empirical research was conducted among the seaports in Northern Europe. The results of the survey may be of interest to seaport authorities and cruise ship owners.

1 INTRODUCTION

In recent years, we can observe a noticeable intensification of port authorities' efforts for the sustainable development and environmental management in seaports (16), (17). On the one hand, it arises from the restrictive regulations of international organizations and institutions, and on the other, pressure from the immediate vicinity of seaports. Port authorities have different objectives in the area of environmental management, including in particular: reduction of harmful substance emissions into the environment, including mainly CO2, SO2, NOx , reduction of energy consumption, increase in energy efficiency, and reduction of noise and vibration levels; (18), generated by ships and port facilities, etc. The Environmental Management System (EMS) procedures are introduced in ports, to enable a systemic approach in managing the port sustainable development. The Port Environmental Review System (PERS) developed by the EcoPorts which is the main environmental initiative of the European port sector is one of the more well-known environmental management systems. This system is based on the ISO 14001 standard. However, this article does not analyse the types of environmental management systems used in seaports. The activities of ports regarding the investments in the area of shore-side energy supply

for cruise ships have been analysed here in detail. The Directive 2014/94/EU on the Deployment of Alternative Fuel Infrastructure is the basis for port efforts to develop onshore power supply infrastructure. In recent years, we can really observe a noticeable intensification of seaport investment activities in this area. In many ports, such installations are already available, but mainly for small vessels and ferries that do not require much power (max <3 MVA).

The aim of this paper is the assessment of seaports' involvement in Northern Europe in the preparation of seaport infrastructure enabling cruise ships to be connected to onshore powers supply system. The article contains the results of surveys conducted with using of two research methods to adjust the research technique to the respondents' needs, i.e. CASI (Computer-Assisted Self Interviewing) and EMS (Electronic Mail Survey).

For the purposes of research, the following research questions were formulated, i.e.: Which seaports in Northern Europe have the onshore power supply for giant cruise ships? Which ports in Northern Europe offer the onshore power supply for giant cruise ships? Which ports plan to invest in onshore power supply for giant cruise ships? What factors influence port authorities' decisions regarding the investments in onshore power supply for giant cruise ships?

The article comprises seven parts. It begins with an introduction and the theoretical approach to issues related to finding solutions in the area of energy saving and reducing the level of pollution emitted by cruise ships to the environment, when they stay in ports and are supplied with shore-power supply. Then, the methods of implementing the research process were described. The description includes the methods, techniques and instruments used in the implementation of research. In subsequent chapters, the results of research and the discussion on research results are presented. The article ends with a summary containing conclusions drawn after analysing the results, and the description of limitations and recommendations for future research related to the analysed subject.

2 THEORETICAL APPROACH

The issues related to ship power supply and port authority investments in onshore powers supply (OPS) have recently been the subject of numerous research and scientific analysis. Several trends of research can be distinguished here; the first refers to power supply systems on ships (22), and the second to the infrastructure at the quays in ports. (32)

A lot of research concerns the optimization of energy consumption on ships and the search for opportunities to introduce new technological solutions to increase energy efficiency. G. Barone et. al. (2021). G. Barone et. al. (2021) (2) described the optimization of ships energy systems. An important part also refers to research on adapting cruise ships to be connected to shore-side energy. Unfortunately, currently few vessels have this type of equipment, but the situation is improving year by year, as shipowners invest significant resources in this type of solutions. (20) However, most of the publications concern mainly the engineering aspects (27), (19) and far fewer are dedicated to the economic and social issues.

Interesting research was also conducted by the team of José E. Gutierrez-Romero et. al. (2019) (11), where they analysed the implementation of OPS from renewable energy sources. Moreover N.N. Abu Bakar et. al. (2023) (1) described electrification of OPS in maritime transportation as the way for decarbonisation of the seaports. Furthermore, L Wang et. al (2021) (30) proposed the bilevel hybrid economic approach for optimal deployment of OPS.

In the Baltic Sea and North Sea region, various initiatives are undertaken to integrate the community involved in the development of cruise shipping. A good example is the project entitled "Green Cruise Port (GCP) – Sustainable Development of Cruise Port Locations" which was initiated in 2016 (26). The project involved 20 partners, representing different backgrounds including seaports, ship-owners, tourist organizations and cruise lines, representatives of public authorities and research institutes. The project aimed to develop a strategy for the sustainable development of cruise shipping, including primarily encouraging port authorities to make environmentally friendly investments and developing smart transport connections linked to the supply chains. Within the project, three main work packages were implemented, i.e.: Sustainable Energy Supply & Innovative Solutions for Emission Reduction; Smart Cruise Terminal Buildings & Innovative Reception Facilities; and Smart Cruise Port Traffic Solutions & Economic Effects (26). Investments in shore power supply were indicated as one of the most important tasks to perform in the first package.

An important factor that determines the seaport authorities' considerations on the possible investments in the onshore power supply for giant cruise ships refers to the condition of hydrotechnical infrastructure, and above all the depth at port fairways, the depth at the quays in port basins, as well as the length of quays dedicated or provided to cruise ships. The second important factor affecting the investments in infrastructure dedicated to cruise ships in seaports refers to the role the port plays on the maritime cruise market. If a seaport is a typical popular base port or port of call visited by hundreds of cruises ships every year, there are serious reasons to invest in port infrastructure including onshore power supply for cruise ships. Such ports in Northern Europe include: Copenhagen, Stockholm, Kiel, Rostock and Southampton. Numerous cruise ship calls guarantee high demand for shore-side energy services, providing a faster return on investment.

Unfortunately, the cost of investing in onshore power supply is a serious barrier for many port authorities. Certainly, various solutions in this area are already available on the market, but the economic balance is still unfavourable for port authorities, because these investments are very expensive and pay off after many years. Port authorities encourage both local and public bodies to invest in onshore power supply. Such actions are exemplified by the investment in the Port of Bremen/ Bremerhaven,

where the capital from the federal and state governments has been involved (28) and the onshore power supply for cruise ships will soon be put into operation.

Seaport authorities, especially those visited by numerous cruise ships, often face pressure from local communities and environmental organizations to reduce the number of ships in order to reduce the environmental damage they cause. Cruise ships moored to the quays wait for passengers for 8 to 12 hours a day and during this time all on-board equipment is connected to on-board engine power system. This generates considerable vibrations felt by the residents living in port areas, generates noise, and ship power plants burn huge amounts of fuel (4), which results in harmful emissions into the natural environment (10). Providing the possibility to connect cruise ships to shore-side power supply (3) could, in a sense, solve these issues. In addition, the cost of shore-powered energy is much lower than supplying a ship with energy from ship power plants. In some tourist destinations such as: Venice (Italy), from 2021 the mooring of giant cruise ships is prohibited in the Giudecca canal, which is located next to St. Mark's Square. This is the result of the pressure from UNESCO, concerned about the damage caused by environmental pollution (13). Whereas in Dubrovnik (Croatia) the number of cruise ships has been limited to a maximum of 8, which can be handled in the port at the same time.

3 MATERIALS AND METHODOLOGY OF RESEARCH

In the article several methods of data collection were applied, i.e. exploratory method, desk research and survey method. The research was preceded by pilot studies in July and October 2021, and the relevant studies were carried out in the period from November 2021 to March 2022. Thirty two ports from the North Sea and Baltic Sea region were invited to participate in the study, but unfortunately only 9 ports finally decided to take part in the research.

The article presents part of the results of surveys conducted in the above-mentioned ports. The analysis in this article referred only to issues related to preparing the energy infrastructure in seaports as regards the supply of shore-based energy to cruise ships. The research was conducted with the use of two survey methods, i.e.: Computer Assisted Self Interviewing - CASI,, which allows the respondents to complete surveys in person, and the Electronic Mail Survey – EMS, method, i.e. a questionnaire sent by e-mail to the respondents. The questionnaire used in the research consisted of 21 questions, including 15 closed questions and 6 open-ended questions, allowing the respondents to answer freely. The research focused on various aspects of seaport sustainability activities, including but not limited to monitoring pollution indicators in ports, issues related to port investments in increasing energy efficiency and applied technological solutions in this respect. This article involves only part of the research results related to the onshore power energy systems investments in ports, and the remaining analyses of research results have been published in other scientific papers. The article also involves scientific publications and reports from seaports as well as the most important legislation regarding energy efficiency and sustainable development. The results of research were subjected to comparative, logical and critical analysis.

4 THE RESULTS OF THE SURVEY

Currently, according to CLIA, only 32% of global fleet capacity is equipped with Shore Side Electricity (SSE), but 58% of new capacity is committed to be OPS compatible (5). Investments in onshore power supply (OPS) make a great challenge for seaport authorities. The on-board power systems and the onshore power energy supply systems differ (6,6/11 KV & 50/60 Hz). This means that the need to invest in transformers and frequency converters. On average, cruise ships, depending on their gross registered tonnage, also have different energy needs, i.e. on average from 3 to 16 MW (23). In Northern Europe, only a few seaports offer the possibility of connecting cruise ships to shore-side energy. The situation is much better when it comes to connecting ferries to shore power. These types of installations are located in ports in: Stockholm, Gothenburg, Kristiansand, Oslo and Gdynia.

In Copenhagen (Denmark), the largest base port of the Baltic Sea, there is still currently no onshore energy supply system dedicated to the cruise ships, while the port authorities plan to invest in this area and 3 onshore power points at Oceankaj berth and 2 onshore power points at Langelinie berth are to be launched in 2025. (7)

The port of Tallinn (Estonia) is considered to be one of the most important ports of call in the Baltic Sea Region. It has currently five new modernized cruise berths. Furthermore, a modern ferry terminal has recently been opened there, using modern technologies to increase energy efficiency and energy saving. Unfortunately, when it comes to OPES, the Tallinn port authorities has been planning such investments on the quays for the future. (7)

The Port of Roenne (Denmark) However, onshore power energy supply systems for cruise ships are only available in Kiel, Rostock, Hamburg and Kristiansand. (23) From 2021 the o OPES is available in Warnemünde (Rostock-Germany) and gives the possibility of connection up to 20 MVA of electrical energy. Thanks to the use of integrated frequency converters, shore-side electricity is converted to international standards of the shipboard power systems (25). (table 1).

In the port of Kiel (Germany) shore power for cruise ships is offered on four quays, three of which are on the so-called “shore power plants” (Ostseekai B.27, Ostseekai B.28 and Ostuherhaven B.1) and one so called “on-shore power connecting point” at the Norwegenkai B22. A maximum power input at this berth amounts to 4.5 MVA at an electric voltage of 10 KV and a grid frequency is 50 Hz. (24) (table 1).

In Germany, the next OPS dedicated to the maritime shipping will be installed by the end of 2023.

Ten onshore power energy systems dedicated to the maritime shipping including one at the cruise terminal will be installed at the Port of Bremen/Bremerhaven. This investment will consume a total budget of 36.4 million US dollars. This is a result of an agreement signed between the federal and state governments who decided to finance this investment. Currently, the port of Bremen and Bremerhaven currently has at its disposal one system for small ships up to 110 m in length.

Table 1 Onshore energy supply system on the cruise berths of the surveyed seaports

Name of the Seaport	Cruise berths parameters Max. Length	Max. Draughth	SSE (shore side electricity)
Port of Rostock			
Pier 1-4	240 m	7,3 m	-
Pier 7	295 m	9 m	PowerCon
Pier 8	330 m	9 m	PowerCon
Pier LP 31	330 m	9.3 m	-
Port of Turku			
River Aura Pier 1	130 m	7 m	-
River Aura Pier 2	80 m	6 m	-
Pier 23	220 m	8 m	-
Pier 25	240 m	8 m	-
Pier 35 – 36	240 m	8,5 m	-
Port of Mukran			
Quey 2	365 m	9,5 m	-
Port of Roenne			
Krydstogtskajen P31-32	250 m	9 m	-
Tværmolen - P22-23	130 m	7 m	-
Kulkajen - P13	160 m	7 m	-
Multipier - P34	350 m	11 m	-
Port of Bremen & Bremerhaven			
Columbus Cruise Center	1000 m	9,8 m	From 2023
Port of Stockholm			
Nynäshamn Seawalk	500 m	15 m	-
Buoy at Strömmen	400 m	25 m	-
Stadsgården 160	300 m	7,4 m	From 2024
Stadsgården 167	500 m	9,4 m	From 2024
Värtahamnen 511	266 m	10 m	-
Skeppsbron 105	130 m	6 m	-
Frihamnen 638	400 m	9,5 m	-
Frihamnen 634	300 m	9 m	-
Frihamnen 655	350 m	9,1 m	-
Värtahamnen 515	255 m	8 m	-
Port of Kiel			
Ostseekai B. 27	300 m	9,5 m	On-shore power plant
Ostseekai B. 28	300 m	9,5 m	On-shore power plant
Norwegenkai B22	300 m	9 m	On-shore power connecting point
Ostuherhaven B1	8000 km	9,5 m	On-shore power plant
Port Gdynia			
French Berth	350 m	11,5 m	Grid for ferries
Port of Aarhus			
Berth 129/131	320 m	10 m	from 2023
Berth 503	430 m	12,5 m	from 2023

Source: own study(25), (23), (28), (24).

The port of Aarhus (Denmark) will also provide the possibility of connecting ships to onshore power from 2023, as the first Danish seaport. From 2024, two OPS units for cruise ships (Stadsgården 160 and Stadsgården 167) will also be available in the port of Stockholm (Sweden). Currently, there is only one unit for small cruise ships and one for ferries.

However, in Poland, in the port of Gdynia, at the Public Ferry Terminal at the Polish Quay, only OPS was installed to supply energy from the shore to the ferries, because it can only supply electricity from land with the following parameters: 3 MVA; 11 kV; 50Hz/60Hz from the shore power grid 15 kV 50 Hz, unfortunately, which is not enough for cruise ships. At the moment, the port authorities do not plan the investments in this field. The shore power supply only for ferry vessels is also available in the Port of Roenne (Denmark) and the port authorities isn't going to plan any investments in this field.

The research showed that 56% tested ports have a "shore to ship system" but mostly for small ship vessels, usually for ferry vessels and 33% of the ports surveyed declared that they're equipped with a (33) "Shorebox" system. (figure 1).

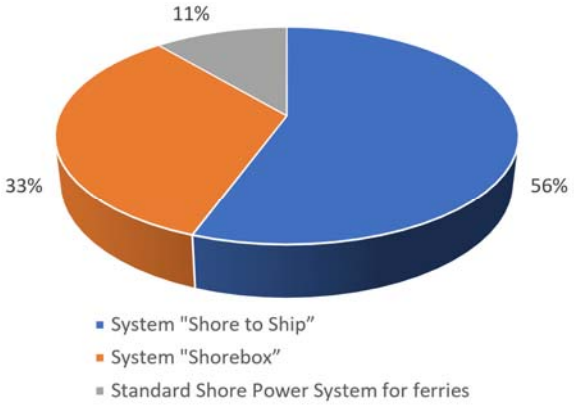

Figure 1. Seaport preparation for shore power supply to cruise ships
Source: own study.

Currently, global cruise companies are introducing larger and larger vessels to the market, which require the preparation of appropriate reception infrastructure in seaports. This poses huge investment challenges for cruise port authorities. The largest cruise ships exceed the length of 360 m and the width of 48 m, and require a draft of up to 10 meters. Unfortunately, as the results of the research showed, only a few seaports have got adequate berths to handle these types of vessels. (table 2).

Table 2. Infrastructure in seaports dedicated giant cruise vessels in the seports in Northern Europe

Name of the seaport	Cruise seaport infrastructure for giant cruise ships (> 360 m the length; 220 thousand GT)	Capital investments planned in cruise seaports for giant cruise ships
Port of Roenne	No	No
Port of Turku	No	No
Port of Mukran	No	No
Port of Rostock	Yes	No
Port of Bremen and Bremerhaven	No	Yes
Port of Stockholm	Yes	No
Port of Kiel	Yes	No
Port Gdynia	Yes	No
Port of Aarhus	Yes	No

Source: own study.

The results of the survey (Table 2) showed that not all ports have dedicated quays prepared for mooring and handling giant cruise ships exceeding 360 meters in length and a tonnage of over 220,000 GT. As a rule, seaports in the Northern Europe have infrastructure that allows the reception of typical cruise vessels (about 3000 PAX capacity). Only a few of them are prepared to receive the largest cruise ships in the world, such as: Oasis of the Seas or Harmony of the Seas. Among the surveyed ports of this type of ships can be moored only in the Port Gdynia Port, the Port of Kiel, the Port of Stockholm, the Port of Bremen & Bremerhaven and also in the Port of Aarhus. These ports have appropriate quay lengths and depths of fairways at quays (table 1).

Table 3. The seaport activities in Northern Europe to monitor energy sources used by cruise ships

Name of the Seaport	Seaport guidelines regarding the use of energy by cruise ships	Monitoring of the source of energy generation by cruise ships moorings at the berth
Port of Roenne	No	No
Port of Turku	Yes	No
Port of Mukran	No	No
Port of Rostock	No	Yes
Port of Bremen and Bremerhaven	No	No
Port of Stockholm	No	No
Port of Kiel	Yes	No
Port Gdynia	No	No
Port of Aarhus	No	No

Source: own study.

It was also checked whether the seaport guidelines regarding the use of energy by cruise ships berthed in the cruise seaport have been developed and made available to the ship-owners. The results of the study showed that only the Port of Kiel and the Port of Turku developed such kind of guidelines. However, the monitoring of the source of energy generation by cruise ships moorings at the berths is carried out only in the Port of Rostock (Table 3).

5 DISCUSSION

Bearing in mind that the most important international institutions and organizations introduce strict guidelines and regulations regarding the level of pollutant emissions from ships into the environment, seaport authorities must implement environmental management systems and invest in new energy-saving technologies to eliminate the level of pollution generated by ships moored at the quays.

At present, the restrictions and strict regulations on the level of CO2, NO2, and SOx emissions into the environment provided in the MARPOL Convention (12), and also in the Agenda for Sustainable Development (29) and the European Green Deal (9) constitute the point of reference in port activities for the sustainable development. The main assumption is to achieve a reduction in net greenhouse gas emissions by at the level of 55% by 2030 and net-zero greenhouse gas emissions (5) by 2050. Admittedly, these are very ambitious plans, considering the current progress of port activities in this respect. These restrictions force seaport authorities to take measures to modernize the existing infrastructure and invest in new technological solutions (17). Port authorities also monitor the level of pollution emitted from ships, and introduce various incentives in the form of discounts and rebates for ship-owners for their use of port infrastructure. The most popular indicator monitored in ports is Environmental Ship Index (ESI) (8). This indicator is used to determine the level of fees in most seaports for the use of infrastructure and services provided in the port. (16)

Cruise ship owners and designers make every effort to find various solutions to save energy and reduce the costs. The ships are equipped with devices enabling them to be connected to onshore power supply, but this is an expensive investment of 0.5 million to 10 million Euros depending on the tonnage of the vessel. (6)

In the ports analysed, there are the so-called "shorebox" systems, on-shore power plant or on-shore power connecting points. Meanwhile, on the market, we can observe various OPS infrastructure solutions: mobile power generator units with combustion engines, air-cooled frequency converters (from 50 Hz to 60 Hz voltage), compact modular cabling system and main transformer station with local stations at the berths. (17)

Ships connected to OPS generate savings for ship-owners, and most importantly have an impact on reducing the demand for energy generated by ship power plants, which significantly reduces the amount of pollution emitted to the environment in the port, reduces vibrations and engine noise, and this is extremely important for the comfort of life of local communities living in the vicinity of ports. Ship-owners apply various solutions on their ships as part of their search for opportunities to save energy and increase energy efficiency: hybrid engines; electric propulsion systems, and also solutions combining solar panels, photovoltaic panels; installation of collectors on sunny parts of a ship, LED luminaires and solar lighting, but also chilling water network chillers are applied to produce the cooling. (14)

It should be emphasized that seaport authorities face great challenges to adapt the infrastructure to the increasingly larger vessels and provide them with access to new technological solutions in the area of energy consumption. The currently built ships can take on board over 6,500 passengers and almost 3,500 crew. The capacity of recently built vessels exceed 220 000 GT, 380 meters in length, and even 47 meters in breadth. (15) Such giant vessels generate huge demand for energy to ensure smooth and reliable operation of all equipment, machinery and devices on board, and serve thousands of people.

The analysis conducted shows that actions in favour of the onshore power supply installations are taken in an increasing number of seaports in Baltic Europe. Taking into account the environmental advantages of connecting ships to shore-side power supply, it seems that this is the right direction, but the analyses of economic efficiency in using this infrastructure still make port authorities hesitant to start these investments.

6 CONCLUSIONS

The results of the studies showed that seaport authorities see the advantages of investments in onshore power supply but on the other hand they also realize that the investments in this field are very cost-intensive and require public co-financing, as it is in the case of the port of Bremen/Bremerhaven. Such solutions are very important for sustainable development of the coastal areas. The situation is much worse when it comes to OPS for giant cruise ships, which require much more connection power. The largest cruise ships need such power as an average small city and this is not economically justified, but it is of a great importance for environmental protection.

The analysis of research results showed that:

- The analysed seaports in Northern Europe make investments to increase energy efficiency and reduce the level of pollution emitted from ships when they are berthed at the quays. This is demonstrated, for example, by the planned investments in the port of Stockholm, the Port of Bremen and Bremerhaven and the Port of Aarhus.
- The majority of ports in Northern Europe (e.g. Roenne, Stockholm, Gothenburg, Kristiansand, Oslo and Gdynia) already have quayside energy infrastructure to connect small vessels, mainly low-power ferries < 3MW, and most of them no longer plan to invest in higher capacity OPS for economic reasons.
- Currently onshore power supply for giant cruise ships are only available in Kiel, Rostock, Hamburg and Kristiansand and in Warnemünde (Rostock-Germany). The giant cruise ships require installed power from 6MVA to 20 MVA.
- The use of integrated frequency converters allows shore-side electricity to be converted to the international standards of the shipboard power systems but the high cost of OPS maintenance discourages seaport authorities from investing in such solutions.
- Investments in onshore power supply systems for giant cruise ships are very cost-intensive since they require huge connected load; therefore they are made mainly by port authorities in cruise ports classified as popular and year-round ports, where the frequency of cruise ship calls provides the return on investment and is economically effective.
- Investments in onshore power supply should be co-financed from public funds since reducing the level of pollution emitted by ships during their stay in ports and increasing the energy efficiency is a matter of common interest, including in particular the local authorities of coastal regions and their residents.
- It seems important to look for technological solutions providing a reduction in cruise ships' demand for shore-based energy. In recent years, we can see that ship-owners are looking for such solutions, which is manifested in installing them on new vessels and modernizing the current fleet through the use of ecological solutions on ships in the form of, for example: combining solar panels, photovoltaic panels; installation of collectors on sunny parts of a ship, LED luminaires and solar lighting etc. These actions will certainly bring the expected economic and environmental effects in the long-term perspective.

In conclusion, it should be emphasized that the situation is not easy either for seaport authorities or ship-owners. Both of them face the challenges imposed by international institutions in the area of environmental management. The goal set to achieve net-zero greenhouse gas emissions by 2050 is an ambitious task. It should also be remembered that it is sea transport that generates the largest amount of greenhouse gas emissions to the environment. Therefore, entities throughout the maritime supply chain must pursue policies for the sustainable development and the reduction of harmful emissions into the environment. Investments in onshore power supply can be one of the important elements of the seaport investment policy.

7 LIMITATIONS & RECOMMENDATIONS

The author is aware about the limitations resulting from the research conducted and the research methodology applied. The research was carried out with the use of the CASI and EMS methods, and despite the fact that the research covered a total of 32 of the most important cruise seaports in the Northern Europe, only 9 agreed to participate in this research. Consequently, the research results should be analysed with great caution and treated more as an analysis of case studies, because these are certainly not representative studies, but targeted studies. In order to supplement the information that could not have been obtained as a result of the survey, the author also applied the exploratory method and used the data available in annual reports and strategic documents of seaports.

The future studies could refer to the analysis of investment costs related to the construction of infrastructure in the area of OPS and the assessment of economic efficiency of this type of investment. The seaport authorities most often point to the fact that maintaining OPS is a significant barrier to their decisions on undertaking such projects. The presentation of the sources of financing such investment and the financial projection using various scenarios could be an interesting cognitive material for port authorities and other stakeholders.

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