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Comparative Analysis of Ports on the Eastern Baltic Sea Coast

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Abstract: Ports are an important part of the global and regional freight supply chain and transport network. *Background*: as port activities have a significant impact on the economic growth of these countries, it is necessary to constantly analyse and plan port activities, anticipate market changes and improve the ability of ports to withstand the growing general competitive pressure. This article analyses studies conducted by researchers on the topic of seaports, thus, and find that there are no analyses comparing more than two ports. *Methods*: a comparative analysis of the ports on the eastern shore of the Baltic Sea was conducted using the analysis of statistical data. *Results*: The Baltic Sea is surrounded by nine countries. Four countries (Lithuania, Latvia, Estonia and Russia) have different coasts and different numbers of seaports. In this article, according to the selected parameters, 10 ports on the eastern coast of the Baltic Sea are analyzed. *Conclusions*: The comparative analysis of ports on the eastern Baltic Sea revealed that Klaipeda port is the most diversified port in the eastern Baltic Sea region, given that it does not have any single most important type of cargo. The largest ports in terms of bulk cargo are in Tallinn, Riga and Ventspils. Primorsk is the largest port for liquid cargo and St. Petersburg handles the greatest volumes of cargo of a general type and while the distribution of cargo flows in the port of Visotsk is best correlated with the selected parameters, which allows us to state that the infrastructure of this port is used to the maximum.

Keywords: eastern Baltic Sea coast; port; competitiveness; draft; port equator; cargo

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1. Introduction

In the process of international trade, maritime transport is one of the most important modes of transport in the global trade chain. Almost two thirds of all world trade cargo is carried by sea, with more than 130 countries developing their national and/or international trade via vessels. The importance of maritime stevedoring business development has grown significantly over the last decade. It has become very important for ports to improve the quality of their services, to introduce the latest technologies and innovations so that they become competitive with other ports. Competitiveness has become one of the most important motives for ports to expand and improve. The increase in the number and specialization of terminals in seaports, the improvement of machinery and the growing volume of cargo from distant countries show that port countries are increasingly inclined to invest in maritime transport, as its benefits to both the state and the population are enormous [1].

Traditionally, port activities have been assessed in order to calculate and improve or optimize the operational productivity of their cargo handling by comparing their current and optimal capacity. From a scientific perspective, these issues have been analysed by Talley, Robinson, Cullinane, Coulson-Thomas, Ng and Liu, Kerk and Alvarez-SanJaime et al. [2–8].

The methods presented in the scientific literature allow us to evaluate the technical efficiency of ports only, absolutely disregarding the financial aspect of port activities as a component of competitiveness. Meanwhile, methods of financial analysis have been widely analysed [9–15]. However, these analyses have not been adapted for assessing port activities, although the financial performance of port activities is clearly one of the key components of competitiveness [1]. On the other hand, in carrying out and developing international trade, operators aim to carry cargo at the lowest possible cost, while it is maritime cargo carriage in particular, which allows operators to not only carry much larger cargo than land transport, but also to minimizes costs by replacing manpower with machinery. For this reason, seaports seek to modernize their equipment and improve their technology, as this allows them to serve a wider range of vessels and to ensure maximum cargo handling and cargo safety. Every solution in this business is optimized because with high handling volumes, every mistake is very expensive. It is, therefore, important to bear in mind that the maritime transport sector is an integrated system that combines several elements, such as seaports, shipping management companies, freight forwarders, logistics companies, distributors, etc. [16]. The features of comprehensiveness of the maritime transport sector create preconditions for the analysis of a comprehensive combination created by these elements in terms of its performance. Based on the results of Arvis et al. [17] and the research of Ibrahimi [18], who has created a model of the maritime transport sector, we know that all the elements that make up the concept of the maritime transport sector carry out activities directly related to the port and shipping business processes. Such activities include logistics, shipbuilding and repair, stevedoring, research, ports, bunkering, agency, the provision of specialized services, etc. Companies in such a pool operate in a specialized market using port infrastructure and port services and develop know-how using human resources and open data [19]. Due to the lack of data and/or difficulties in obtaining data, scientific articles often analyse the problems of a particular port and perform various simulations. In our opinion, the analysis of the scientific literature on maritime transport activities is, in principle, complicated by the fact that it is a sufficiently specific field of study in which there are not so many scientists compared to other modes of transport. There are also a number of restrictions on access to information, including confidentiality, amongst other reasons, for research in this sector. We are all well aware that ports are a strategic location for each country, both for the movement of cargo/passengers and for military operations. Therefore, a larger number of the articles are more focused on the efficiency of terminals or a specific company, the movement of material flows and so on.

The aim of this article is to provide a comprehensive comparative analysis of the ports on the eastern Baltic Sea coast.

The following tasks were set to achieve this goal:

- to evaluate the competitiveness of ports based on a range of elements from a scientific point of view;
- to analyse the ports of the eastern Baltic Sea coast from a quantitative perspective.

2. Methods and Methodology

This section consists of two subsections, one of which focuses on the substantiation of the problem and the application of the existing methods and methodologies in the assessment of port competitiveness and while the other briefly defines the methodological guidelines for the cross-sections to be used in the analysis of the competitiveness of the eastern Baltic Sea ports.

2.1. Literature Review

To increase the efficiency of port operations, reforms were carried out in the majority of ports in late-twentieth century, one of the main objectives of which was to ensure competition as the key tool for achieving efficiency. In general, the competitiveness of ports is related to the volumes of and opportunities for exports and imports. However, port competition is a rather broad concept, encompassing many different factors. The complexity and dynamics inherent in ports allows us to look at port activities as a broad and open functioning system or model [20].

Different authors emphasize different factors that determine the competitiveness of ports. The concept of competitiveness is understood quite differently, not only by individual economists, but also by different countries. This is because competitiveness is a highly complex concept, rather than a situation or condition measured by certain uniform criteria. However, competitiveness can be said to be related to operational productivity in all cases.

The competitiveness of ports is one of the most important components of the successful operation of the transport system. A high level of competitiveness in the international market means that ports are able to provide quality services, ensuring high levels of exports and imports.

Noritake and Kimura, Sölvell and Puidokas and Andriuškienė [21–24] summarized the main areas of assessment of seaport competitiveness and distinguished the following elements: port depth, port development, creating and improving the image of ports, increasing port capacity and maximizing port security and reliability.

According to Nemuraitė [20], port competitiveness can also be divided into several levels: competition between regions, competition between individual ports, internal port competition between individual terminals and competition between modes of transport.

However, it is important to note that both external and internal factors determine the competitiveness of ports:

- **External factors determining port competitiveness.** The factors driving changes in ports in the global and national context should be analysed by grouping them into certain groups. PEST analysis is one of the most common methods for analysing the external environments that determine the activities of a certain object.
- **Internal factors determining port competitiveness.** In this case, the theory of inputs and outputs is used in the analysis of factors. According to the theory of inputs and outputs, the internal factors of port competitiveness can be divided into four main categories: (1) human factors, (2) institutional factors, (3) physical-technological factors, (4) economic factors.

In her research, Bogatova [25] examined the determinants of the competitiveness of seaports at the end of the twentieth century identified by different researchers and distinguished the following factors by year:

- key factors in 1980: confidence in port schedules, the frequency of ship entries, the variety of shipping routes and port availability;
- key factors in 1981: navigation distance, proximity to land, connections with other ports, the availability of port equipment and port taxes and service charges;
- key factors in 1984: average waiting time in a port, confidence in port schedules and the supply of port services for port infrastructure capacity;
- key factors in 1985: port dues and service charges, port availability and interconnected transport networks;
- key factors in 1984–1985: port dues and service charges, the frequency of ship entry and port reputation and/or loyalty and cargo damage cases;
- key factors in 1988–1992: loading and unloading equipment for large and/or substandard size cargo, the possibility of servicing large volumes of shipments, few cases of damage to cargo and losses, available equipment, convenient pick-up and delivery times, information regarding the process of service provision, assistance available for claims handling processes, the flexibility of meeting special stevedoring requirements;
- key factors in 1990: internal factors: service level, available infrastructure and equipment capacity, the condition of infrastructure and equipment and port operation policy. External factors: international politics, changes in the social environment, the trade market and economic factors, the characteristics of competitive ports and functional changes in transport and materials handling;
- key factors in 1992: geographical position, land transport networks, transport accessibility and efficiency, port dues and service charges, port reliability and port information system;
- key factors in 1994: port infrastructure and equipment, internal transport networks, container transport routes, geographical position, domestic rail transport connections, investments in port infrastructure and equipment and the reliability of the port workforce;

- key factors in 1995: port dues and service charges, cargo handling security and confidence in port schedules;
- key factors in 1996 and 2000: customs services, fast service, the simplicity of port documents, guarantees for cargo damage, the qualification of port employees and the reputation of the port.

The research by Žimkus [1] examined the determinants of seaport competitiveness in early 21st century Alvarez-SanJaime et al. [8] on the basis of work carried out and identified 17 factors that determined the competitiveness of seaports at the beginning of the 21st century.

In summary, competitiveness of seaports can be said to be mainly determined by the technical parameters and geographical location of ports, level of infrastructure development, price and quality of services and port capacity. To strengthen competitiveness, specialists in the field emphasize parameters of maritime transport connections, efficiency of port operations, connections with mainland transport systems and the quality of organizational activities [7].

According to Ramanauskas [26], competitiveness assessment methodologies can be divided into five groups: (1) methodologies for evaluating competitiveness indicators; (2) methodologies for assessing the competitiveness of economic sectors; (3) methodologies for assessing the competitiveness of the regional/national level; (4) methodologies for assessing the competitiveness of international level; (5) methodologies for assessing the competitiveness of economic policy.

In 2002, a researcher at the University of Antwerp in Belgium applied the Porter diamond competitiveness model to assess port competitiveness. Meanwhile, Coulson-Thomas [5] recommends to use Porter's international competitiveness assessment model to assess port competitiveness, distinguishing between factor conditions, demand conditions, related and supporting industries, corporate strategy, structure and competition.

Abbes [27] emphasizes that measuring and assessing the competitiveness of seaports is an important academic interest, but there is very limited empirical research on the matter in some regions (for example, in African seaports, etc.). In such a case, an analysis is often conducted using the main components only. In each case, the analysis of the competitiveness of ports is hampered by a lack of or a limited access to information. Therefore, researchers examine different parameters in each case. For example, Abbes [27] used the World Bank's database and conducted an analysis of the competitiveness of African ports according to the following indicators: capacities TEU (CAPA); export price in US dollars per container (EXPO); import price in US dollars per container (IMPO); number of imported documents (DOCS); liner connectivity index (CONECT); and the quality of port infrastructure (INFRA).

Konvisarova et al. [28] emphasized that many authors abroad and in Russia assessed the competitiveness from different perspectives, including the cost approach, the innovative approach and the supply chain. Therefore, the authors relied mainly on a theoretical research method, including the analysis and synthesis, a systematic approach and comparison, abstraction, historical method, induction and deduction and generalization and formalization.

In their research, Munim and Saeed [29] reviewed articles focusing on the competitiveness of seaports published in maritime literature, where bibliographic data collected from the ISI Web of Science database consisted of 267 scientific papers by 465 authors and 117 journals. The main disciplines reflected in the 267 articles selected from the ISI Web of Science database covered transport (42%), economics (23%), geography (11%) and management (9%), while the distribution clearly shows the interdisciplinary nature of this research area.

However, in recent years, the majority of authors, such as Ng and Liu [6], advocate for the use of multi-criteria analysis methods in the process of assessing the competitiveness of seaports, giving unequivocal priority to the analytic hierarchy process (AHP).

When treating the competitiveness of the seaport as the ability to use internal competitiveness factors, adapting to changes in the external environment, identifying the most significant changes in the business environment and examining the ways of assessing the impact of business environment factors is expedient. Timely and objective assessment of changes in the business environment helps to strengthen the seaport's positions in the international market. Globalization has turned competitive advantages in maritime business into much more mobile, knowledge-intensive and more widespread in the geographical area, which in turn significantly expands the field of the analysis of the impact of the business environment.

Therefore, traditionally, port activities have been assessed in order to calculate and improve or optimize operational productivity in cargo handling, comparing the existing and optimal capacity. However, many authors view ports from different perspectives. For example, Bogatova [25] emphasized that:

- Talley [30] presented a methodology for analysing the productivity of container ports, offering to measure the function of economic productivity and economic costs based on the number and weight of containers served.
- Tabernacle [31] emphasized the impact of characteristics of container cranes used in ports on the efficiency of port operations: the more efficient the crane, the faster the ships are served in the port and the better is the port capacity.
- Tongzon [32] conducted an empirical study analysing the performance of 23 international ports and the impact of port infrastructure on port efficiency.
- Kim [33], Kim and Bae, and Kim and Kim [34,35] analysed the impact of container arrangement and the number of transfers between cranes on port efficiency.
- Wilson and Roach [36] analysed the opportunities of using artificial intelligence to optimize cargo handling, arrangement and warehousing in ports.

There have been very few attempts to make a generalized assessment of port performance, for example, by measuring one factor, productivity De Monie [37], or by comparing an actual an optimal performance over a certain period of time [2]. In the past few years, efficiency related to production activities has been assessed more frequently. Two more sophisticated holistic methods have been used to achieve this goal, namely, the data envelopment analysis (DEA) and the Stochastic Frontier Analysis (SFA).

In the operation of ports, it is important not only whether they can physically cope with cargo flows, but also whether competition for cargo is possible. The methods presented in the scientific literature allow to assess the technical efficiency of ports only, absolutely disregarding the financial aspect of ports or the perspective of creating a competitive advantage. Meanwhile, financial analyses have not been adapted for investigating port activities.

An analysis of the latest research shows that research into the link between efficient seaport management and the appeal of the maritime transport sector is rather fragmented, segmented and one-dimensional, with some of them focusing on efficient management of the seaport and others on creating the appeal of the maritime transport sector in the problem field of research [19].

According to Valionienė [19], the economic perspective of activities of seaports and the area of competitive advantages have been explored extensively. Sufficient research has been carried out to analyse the relationship between the efficiency and management models of seaports and business entities operating in them, changes in port operations and competitiveness and the importance of regional and global seaport integration for both changes in port competitiveness and attracting cargo flows to regions in [38–41], assessing the importance of seaports for national and regional economic change [42–44].

The analysis of research conducted by foreign researchers revealed that the topics of the majority of studies are related to the analysis of the current situation in the management of seaport management and/or implemented cases of modernization of seaport management.

The research by Notteboom and Winkelmans, Notteboom, and Notteboom et al. [45–50] on the efficiency of operations of the state seaport as an object of public administration, as well as on increasing its attractiveness, is based more on the problems of policy-making in the maritime transport sector, which were studied in different sections using different dimensions of analysis. Notteboom was a co-author in a number of other research in this thematic area, continuing theoretical research by [51] and developing the importance of leadership in analysing seaport management problems in his publication of 2013 with Termeer. Pallis, Pallis et al. [52–55] paid a significant attention to the seaport management policy-making at national and European Union level [19].

In summary, there is no single methodology for assessing the competitiveness of seaports and all researchers conduct these assessments on the basis of the information available to them. Therefore, we will use the information collected and provided below in our analysis of the eastern Baltic coast.

2.2. Description of the Assessment Methodology of the Eastern Baltic Ports

In a quantitative research, information about social reality has been collected and stored in the form of numbers. Quantitative research has been used when the studied phenomena are of a mass nature and mathematical statistical methods are needed to describe them and assess their trends. Since quantitative research collects data on social reality in the form of numbers, quantitative data collection methods have strict rules that must be followed in order for the data obtained to be accurate and suitable for mathematical and statistical analysis. It should be emphasized that quantitative research collects information that can in principle be digitized for statistical analysis. One of the methods of quantitative data collection is statistical data analysis or, alternatively, secondary data analysis.

An analysis of the scientific literature has shown that there are many and varied methods for analyzing ports, terminals and stevedoring companies, but when analyzing port infrastructure statistics, it can only be done using official information provided in official, publicly available documents or websites. Quantitative and qualitative analysis is only possible with the formal consent of the companies, which undertake to provide information for the ongoing research and to allow the results to be made public. The methods mentioned in Section 2.1 (methodologies for evaluating competitiveness indicators; methodologies for assessing the competitiveness of economic sectors) were only partially used in the comparative analysis of the ports of the Eastern Baltic Sea.

So, the method of quantitative research was chosen for competitiveness analysis. Quantitative research was selected in order to find out the competitiveness of all Eastern Baltic Sea ports, according to the following criteria:

- port depth: maximum depth (m);
- port development: length of embankments (m); number of embankments (pcs.); maximum ship length (m); open warehouses (m^2); covered warehouses (m^2); refrigerated cargo warehouses (m^2); liquid cargo tanks (m^2);
- creation and improvement of the image of ports: territory (ha); stevedoring volumes (million tons); number of terminal operators (pcs).

A correlation between cargo flows and the selected port infrastructure parameters will be determined based on the above information.

A correlation is a bivariate analysis that measures the strength of linkage between two variables and the direction of the relationship. In terms of the strength of the relationship, the value of the correlation coefficient varies between +1 and −1. The value of ±1 indicates a perfect degree of association between the two variables. As the correlation coefficient value goes towards 0, the relationship between the two variables weakens. The direction of the relationship is indicated by the sign of the coefficient; a "+" sign indicates a positive relationship and a "−" sign indicates a negative relationship [56]. Since the correlation coefficient is a measure of the direction and strength of the relationship between two sets of variables, a positive correlation coefficient indicates that with an increase of one variable, the other variable also tends to increase, while a negative correlation coefficient means that as one variable increases, the other one tends to decrease [57].

Usually, four types of correlations are measured in statistics:

- Pearson correlation (parametric)

- Kendall rank correlation (non-parametric)
- Spearman correlation (non-parametric)
- Point–Biserial correlation [58].

The relation between two variables is often of interest in data analysis and methodological research. The Pearson, Spearman and Kendall correlation coefficients are the most commonly used measures of monotone association, with the use of the latter two usually recommended for non-normally distributed data [59].

Characteristics of the ports under consideration will be presented below, also providing systematized statistics on the basis of which a correlation will be drawn to assess the interaction between cargo flows and the selected port parameters.

2.3. Ports on the Eastern Baltic Sea Coast and Their Characteristics

Seas cover nearly 70%of the world's surface, and they are the best way to get around. The benefits of maritime transport are clear, accounting for 62% of global freight turnover and 90% of global maritime transport. For many countries, both global economic leaders and developing countries, maritime transport has been and remains a major link to the outside world [60].

The ports of Latvia, Estonia, Poland and the east coast of Russia are on the east coast of the Baltic Sea. The ports of all the three Baltic States are important transit corridors connecting east to west and south to north. The priority European transport corridors pass through the Baltic States, namely (Figure 1):

- Corridor I North-South or Via Baltica (Helsinki–Tallinn–Riga–Kaunas–Warsaw) for transit, export and import cargo;
- IA branch or Via Hanseatica (Riga–Siauliai–Kaliningrad–Berlin);
- Corridor IXB West–East direction (Kiev–Minsk–Vilnius–Kaunas–Klaipeda) for transit, export and import cargo transportation;
- in the railway system: Corridor I (Helsinki–Tallinn–Riga–Kaunas–Warsaw), Corridor IXB (Kiev–Minsk–Vilnius–Klaipeda) and Corridor IX (Kaišiadorys–Kaunas–Kaliningrad) Transport Corridor I, connecting Warsaw with Helsinki.

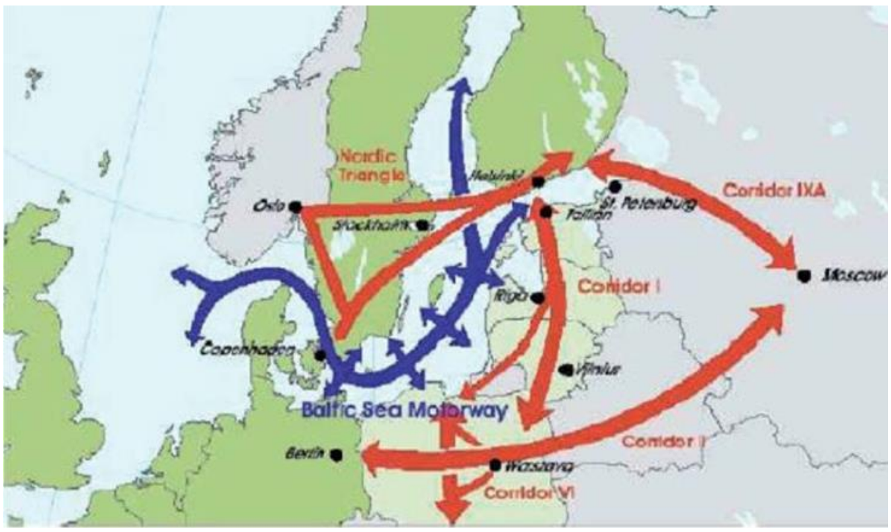

Figure 1. Transport corridors in the Baltic Sea region. Source: Adapted from Ref. [61].

The Baltic Sea is surrounded by nine countries. Four countries (Lithuania, Latvia, Estonia and Russia) have different coastlines and different numbers of seaports comprise the Eastern Baltic. Figure 2 below shows the main ports on the eastern Baltic Sea coast and their geographical location.

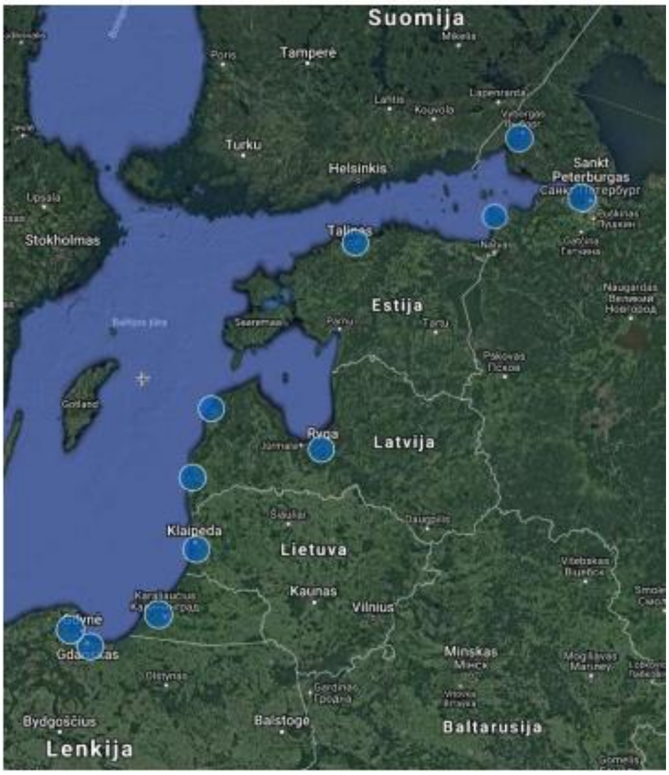

Figure 2. Key ports of the eastern Baltic Sea coast. Source: [62].

This Article analyses 10 ports on the Eastern Baltic Sea coast, which will be analysed by country:

1. **Lithuania.** Having a non-freezing port and being in the central part of Europe geographically, Lithuania can be called a transport bridge between the West and the East. The Klaipeda Seaport (Figure 3) is the closest to ports of West and North Europe and to South Scandinavian ports.

Figure 3. Klaipeda seaport. Source: [63].

The main shipping lines to the continents of Western Europe, America and Southeast Asian pass through the Klaipeda port. Klaipeda is a deep-water, universal, multifunctional port. The quality of services of the port meets all the requirements of the European Union [64]. The main characteristics of the port are as follows:

- the port now covers an area of 1442.8 ha, which consists of the land area of 557.9 ha and the internal water area of the port covering 884.9 ha;
- the depth of the port entrance channel is 15 m and the internal depth of the port channels is 15.5 m;
- the length of port berths—26.8 km, the number of berths—157 [65];
- cargo storage possibilities in the port: area of covered warehouses for general cargo—99,380 m^2, storage capacity of bulk cargo—933,700 t, storage capacity of frozen cargo—66,000 t, area of open storage sites—1,045,879 m^2, tanks for storage of liquid cargo—749,000 m^3 [66];
- the port has the following terminals: 15 cargo terminals, 2 cruise ship terminals, 3 Ro-Ro terminals and 2 container terminals;
- the port handles oil products, containers and general cargo, bulk and liquid fertilizers, mineral and chemical materials, agricultural products, metal products and raw materials, Ro-Ro cargo, liquid and frozen food products, construction materials, wood, peat, bulky and heavy cargo, Ro-Pax, cruise ship passengers and many other cargo [65];
- port capacity: the port accepts 400 m long and 59-m wide vessels with a 13.8-m draft, also large tonnage vessels: dry cargo—about 100,000 DWT, tankers—about 170,000 DWT, container vessels—19,500 TEU;
- intermodality is being developed in the port: container and container trains Mercury, Vikings and Saul connecting the Baltic markets from Klaipeda to Odessa Kazakhstan and China via Minsk, Moscow and Kiev are innovative trains promoting intermodal transport in the Baltic States. Containerization is a global trend that will continue in the future [65].
- Ferries sailing from Klaipeda to Germany, Sweden and Denmark provide good connection to Northern Europe.

More than 800 companies are directly involved in the activities of the Klaipeda port, creating 6.13 percent of the total GDP of Lithuania and more than 58,000 jobs [67]. This shows that the port makes a significant contribution to the improvement of the economic situation in Lithuania and has an important position.

2. **Latvia.** There are three ports in this country:

- **Port of Riga.** It is the main port on the eastern coast of the Baltic Sea, located in the Latvian capital Riga. Historically, Latvia has been one of the main transit countries for north-south and east-west trade. The free port of Riga (see Figure 4) is located on both banks of the Daugava River, which is 15 km long.

Figure 4. Port of Riga. Source: [68].

The main characteristics of the port are as follows:

- the port now covers an area of 348 ha, which consists of the land area of 1962 ha and the internal water area of the port covering 4386 ha;

- the depth of the port entrance channel is 16 m and the internal depth of the port channels—13.5 m;
- the length of port berths is 18 km, the number of berths 152 [69];
- cargo storage capacity in the port: area of covered warehouses for general cargo—418,603 m^2, storage areas of bulk cargo—217,800 m^3, storage capacity of refrigerated cargo—7800 t—and, in addition, area of open storage sites—1,894,278 m^2, liquid cargo storage tanks—522,391 m^3, [69];
- The port has 46 cargo terminals, 2 cruise ship terminals and 3 container terminals;
- The port handles oil products, coal, container and general cargo, dry cargo, liquid cargo, chemicals, agricultural products, metal, Ro-Ro cargo, construction materials, timber, peat, [69];
- port capacity: the port accepts 500 m long ships with a 15-meter draft;
- Intermodality being developed in the port—Container transport services: Riga Express (Riga–Moscow), container train Baltika-Transit (Riga–Almaty), container train Zubr (Riga–Minsk–Illichevsk), block train (Riga–Hairaton) [69].

More than 9%of the Latvian workforce works in or is related to transit services. The transport, transit and cargo storage sectors create 8.7% of Latvia's GDP.

- **Port of Ventspils.** It is the largest port in Latvia and one of the largest in the Eastern Baltic Sea region (see Figure 5).

Figure 5. Port of Ventspils. Source: [70].

The port is a useful transport link between the EU, the CIS and the Central Asia and is considered one of the main network nodes in Latvia and the Baltic Sea region between the East–West transit corridor and the European TEN-T transport network. The main characteristics of the port are as follows:

- the port now covers the area of 2451.39 ha, which consists of the land area of 2226.79 ha and the internal water area of the port of 224.6 ha;
- the depth of the port entrance channel is 17 m and the internal depth of the port channels is 14 m;
- the length of port berths is 11 km, the number of berths—57 [71];
- cargo storage facilities in the port: covered warehouses for general cargo—57,200 m^2, open warehouses—460,000 m^2, refrigerated cargo storage—12,000 m^2, liquid cargo tanks—1,676,000 m^3, [71];
- the port has 15 cargo terminals;
- port handling oil products, coal, chemicals, agricultural products, metal, Ro-Ro cargo, timber, mineral fertilizers [71];
- port capacity: the port accepts 270 m long vessels with 13.2 m draft and the maximum capacity of 150,000 DWT [71].

- **Port of Liepaja.** The port is located 100 km south of the Ventspils port (see Figure 6).

Figure 6. Port of Liepaja. Source: [72].

The main characteristics of the port are as follows:

- the port now covers an area of 2451.39 ha, which consists of the land area of 2208.79 ha and the internal water area of the port covering 242.60 ha;
- the depth of the port entrance channel is 12 m and the internal depth of the port channels is 11 m;
- the length of port berths is 10 km, the number of berths—67 [73];
- cargo storage capacity in the port: area of covered warehouses for general cargo—75,000 m^2, area of open warehouses—440 000 m^2, frozen cargo storage capacity—25,200 m^3, liquid cargo storage tanks—75,000 m^3, silos—74,400 m^3 [73];
- the port has 16 cargo terminals, 2 container terminals and a cruise ship terminal;
- bulk cargo, liquid cargo, general cargo, Ro-Ro cargo ad containers are handled in the port [73].

3. **Estonia.** The Port of Tallinn is the largest port authority in Estonia. The integrated port of Tallinn consists of five ports located in separate territories. The port of Paldiski, the Tallinn Passenger Port and the Muuga Harbour (see Figure 7) are the most important ports.

Figure 7. Muuga Harbour in Tallinn. Source: [74].

It is one of the largest port companies in the Baltic Sea in terms of cargo and passenger flows. The Port of Tallinn acts as a multimodal hub, serving passengers and different vessels every day. The Port of Tallinn has two passenger ports (the Old Town Port and Saaremaa Harbour) and two cargo ports. Muuga Harbour is the largest cargo port in Estonia. It is located about 17 km east of Tallinn. The main characteristics of the port are as follows:

- the port now covers the area of 1784.2 ha, which consists of the land area of the port of 787.2 ha and the internal water area of the port of 997 ha;
- the depth of the port entrance channel is 9 to 18 m (Old City—11 m, Muuga—18 m, Paljassare—9 m, Paldiski South—15.7 m, Saaremaa—10 m);
- the length of port berths is 15,519 km, the number of berths—77 [75];
- the cargo storage capacity in the port: the area of covered warehouses—230,000 m^2, frozen cargo storage area—13,500 m^2, area of open storage sites—695,000 m^2, oil product storage tank—1,550,150 m^3, grain silo capacity—300,000 t, fertilizer storage capacity—192,000 t [75];
- the port has the following terminals: 10 cargo terminals, 2 cruise ship terminals, 2 Ro-Ro terminals and a container terminal;
- in the ports: Ro-Ro cargo handled in the Old City; Muuga—Container and general cargo, bulk cargo (fertilizers, grain, gravel, wood pellets), ro-ro cargo and liquid cargo; Paljassare—mixed cargo, coal and oil products, timber and perishable cargo; Paldiski Sauth—Ro-Ro cargo, liquid products, bulk cargo, general cargo; Saaremaa—Dry cargo (wood, chopped wood, wood pellets, gravel) [75];
- port facilities: the port accepts 340 m long, 50 m wide vessels with the maximum draft of 17.5 m;
- Intermodality is being developed in the port: a shuttle train carrying containers on the Tallinn–Moscow route. The Estonian railway network is directly connected to the railway system of Russia and other CIS countries. On the Trans-Siberian Railway, the Estonian railway network also has connections with the Far East, making it one of the transit hubs between East and West [75];
- The port's shipping lines to Russia, Finland and Sweden provide excellent connections to Northern Europe;
- The port is a part of the Trans-European Transport Network (TEN-T).

4. **Russia.** The country has the following ports:
    - **Ust Luga.** The port is located on both sides of the Luga river, on the northwest coast of Russia, about 130 km south of St. Petersburg. The new deep-water port is located 7 km east of the river banks (see Figure 8).

Figure 8. Port of Ust Luga. Source: [76].

The main characteristics of the port are as follows:

- the port now covers the area of 128 ha;
- the depth of the port entrance channel is 15.2 m;
- the length of port berths is 7217 km, the number of berths—38 [77];
- cargo storage capacity in the port: the area of covered warehouses for cargo—51,700 m^2, the area of open warehouses—471,530 m^2; liquid cargo storage tanks—800,000 m^3;
- the port has 12 specialized cargo terminals for coal, sulfur, container, multi-purpose cargo handling and timber;
- bulk cargo, liquid cargo, general cargo, Ro-Ro cargo and containers are handled in the port [77].

- **Port of Primorsk.** This port only handles oil products carried by Russian oil extraction and refining companies. The port of Primorsk handles the largest volumes of oil in the entire eastern Baltic Sea region. The trading port of Primorsk (see Figure 9) has been on the market for 12 years and has become one of Russia's main oil terminals.

Figure 9. Primorsk Commercial Sea Port. Source: [78].

The main characteristics of the port are as follows:

- the port now covers the area of 252 ha;
- the depth of the port entrance channel is 17.8 m;
- the length of port berths is 20.3 km, the number of berths—13 [79];
- cargo storage facilities in the port: crude oil storage tanks with a capacity of 500,000 tons and diesel for 240,000 tons;
- Port terminal capacity: the maximum estimated crude oil terminal capacity is 75 million tons per year and the diesel terminal—20 million tons per year;
- the port specializes in the handling of oil and oil products [79].

- **Port of St. Petersburg.** This port (see Figure 10) is currently one of the three main ports in Russia.

Figure 10. Port of St. Petersburg. Source: [80].

The main characteristics of the port are as follows:

- the port now covers the area of 121.5 ha;
- the depth of the port entrance channel is 11 m;
- the length of port berths is 5.3 km, the number of berths—31 [81];
- cargo storage facilities in the port: area of covered warehouses—153,000 m^2, area of open storage sites—237,900 m^2, capacity of refrigerated cargo warehouses—14,200 tons [81];
- the port has various cargo terminals, including Ro-Ro and container terminals;
- cargo handled in the port includes ferrous metals, non-ferrous metals, scrap metal, mineral fertilizers, Ro-Ro cargo, bulk materials, liquid cargo, general cargo, containers and oversized cargo;
- port facilities: the port accepts 320 m long and 50 meter wide vessels with 11 m draft and the maximum tonnage of 40,000 DWT [81].

- **Port of Kaliningrad.** This port (see Figure 11) consists of two parts.

Figure 11. Port of Kaliningrad. Source: [82].

One port is located in Kaliningrad, about 46 km from the sea and the entrance to the bay. Another Baltiskij port is located at the entrance to the bay, in the northern part of the Kaliningrad Canal. The main characteristics of the port are as follows:

- the port now covers the area of 230 ha;
- the depth of the port entrance channel is 9–10.5 m;
- the length of port berths is 2.5 km, the number of berths—19 [83];
- cargo storage capacity in the port: area of covered warehouses—44891.7 m^2, area of open storage sites—238,275.8 m^2, area of frozen cargo warehouses—6192.3 m^2 [83];
- the port has various cargo terminals, including a container terminal;

- cargo handled in the port: ferrous and non-ferrous metals, ro-ro cargo, bulk materials, liquid cargo, general cargo, containers and timber;
- the port is at the intersection of the branches of the trans-European transport corridors (No. 1A—"Riga–Kaliningrad–Gdansk" and No. 9D "Kiev–Minsk–Vilnius–Kaliningrad") [83].

- **Port of Visotsk.** The sea port of Visotsk is located on Visotsky Island (Figure 12) in the Gulf of Finland, 90 km from St. Petersburg and 50 km from the Russian–Finnish border.

Figure 12. Port of Visotsk. Source: [84].

The main characteristics of the port are as follows:

- the port now covers the area of 34.02 ha;
- the depth of the port entrance channel is 15.6 m;
- the length of port berths is 681 m, the number of berths—4 [85];
- cargo storage facilities in the port: the area of open storage sites covers 22 ha, allowing to store about 250,000 tons of bulk cargo at a time [85];
- the port has loading terminals adapted for bulk cargo handling;
- bulk cargo dominates in the port [85].

3. Results and Discussion

This section presents the analysis related to ports of the Eastern Baltic Sea and their characteristics, assessing parameters of infrastructure of competing ports and cargo flows.

3.1. Infrastructure Parameters of Competing Ports

One of the biggest advantages of Klaipeda port, compared to other ports on the eastern Baltic Sea coast, is the fact that Klaipeda port does not freeze, while other ports are usually covered in ice during winter. The analysis of the infrastructure parameters of the competing ports are presented in Figures 13–17.

The conducted analysis allows the conclusion that the largest port area on the eastern shore of the Baltic ports is the Latvian port of Venspils covering 2208.79 ha, followed by the Latvian port of Riga with 1962 ha in the second place. These ports are much larger than other competing ports on the eastern Baltic coast. The territory of the Klaipeda port, compared to other ports of the Eastern Baltic Sea, is small (557.9 ha), but compared to the volume of cargo handling in 2020, which was almost 48,000 tons, it is used most efficiently among all the competing ports. Meanwhile, the territory of the three Latvian ports covering 4546.79 ha is used the least efficiently compared to other ports of the Eastern Baltic Sea.

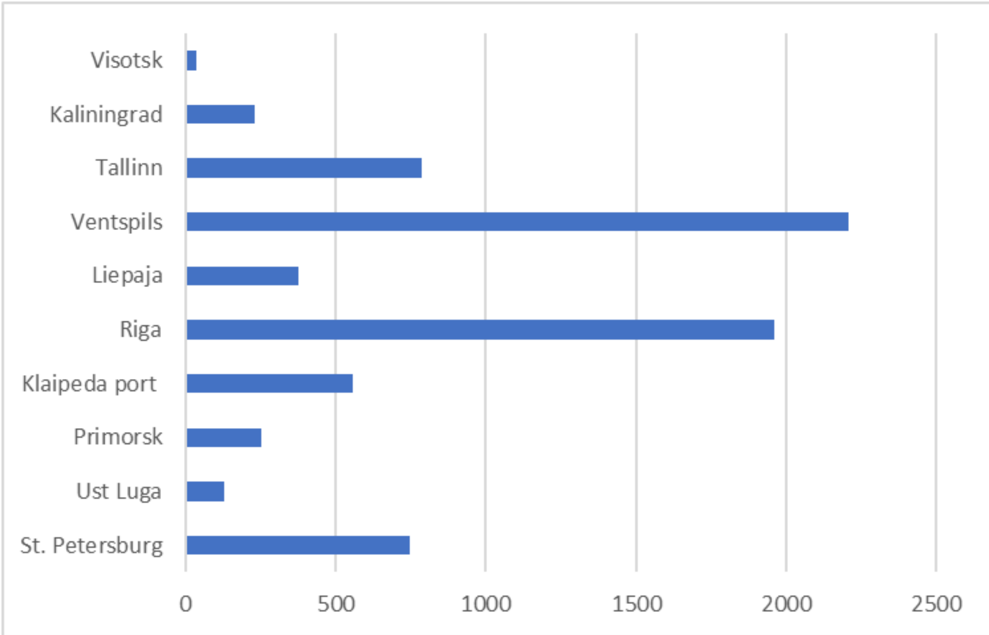

Figure 13. Comparison of the Port area (hectares).

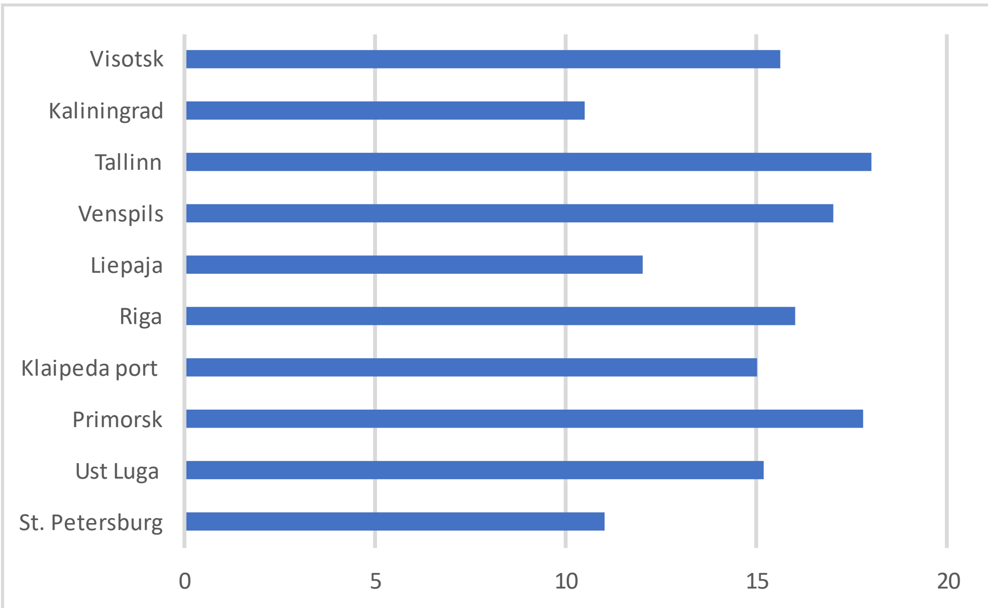

Figure 14. Maximum port depth (meters).

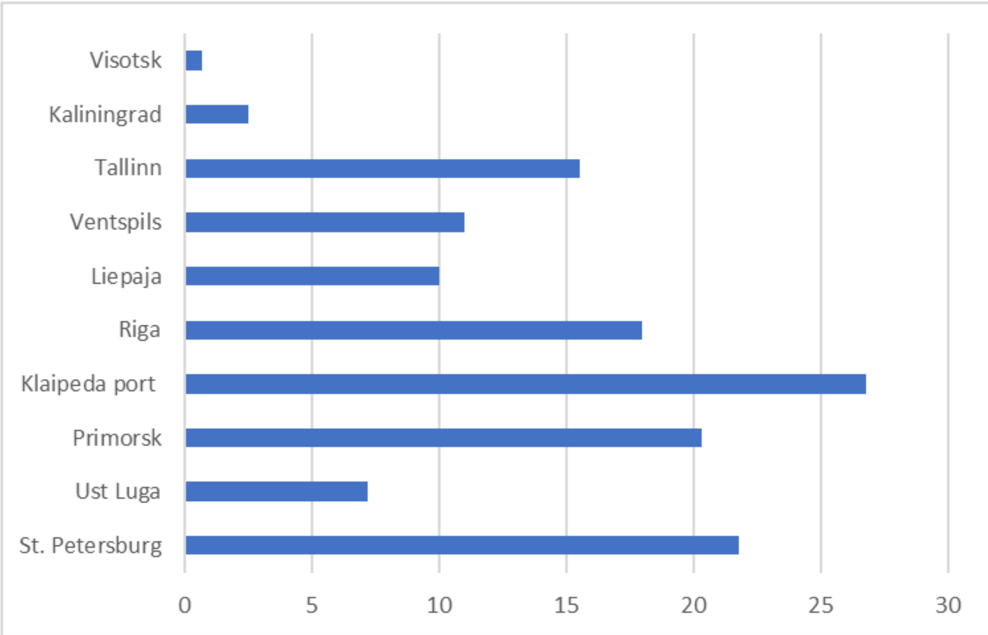

Figure 15. Length of quays (kilometers).

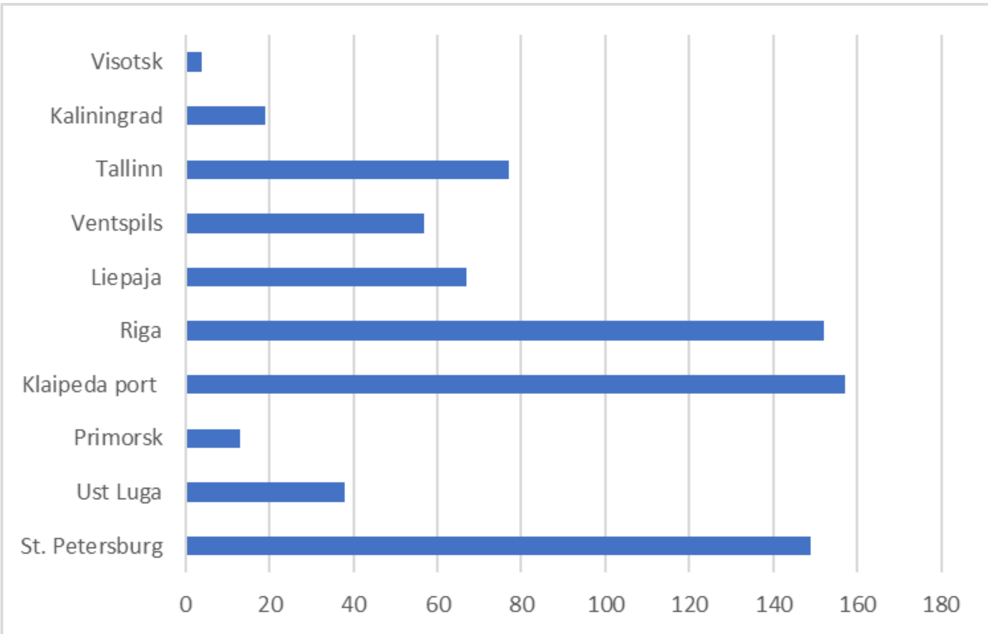

Figure 16. Number of berths (units).

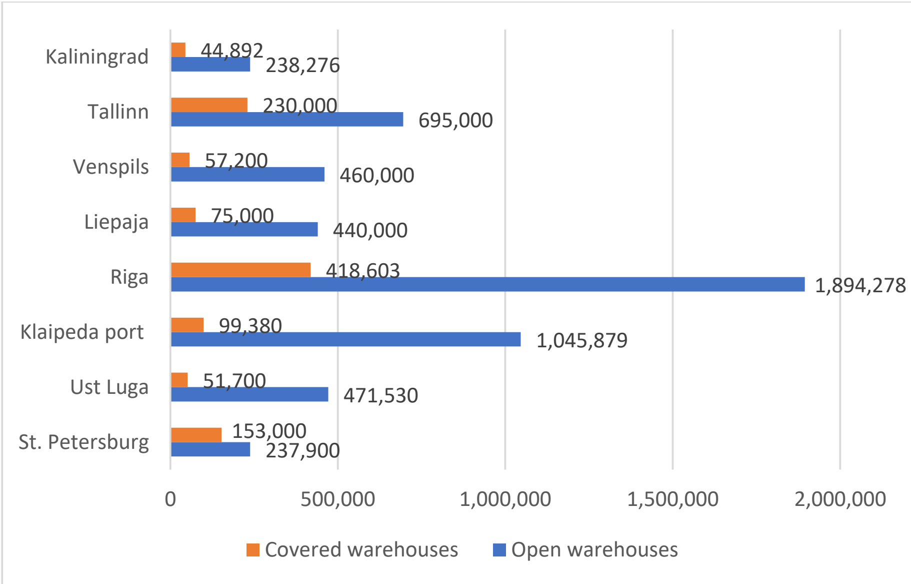

Figure 17. Cargo storage.

The ports of Tallinn, Ventspils, Riga and Primorsk are the deepest ports in the eastern Baltic Sea region. Their depth is 16–18 m, which is the maximum depth of entry into the Baltic Sea near Denmark (18 m). The depth is 17 m in the port of Ventspils and the depth of the port of Primorsk is 17.8 m. The above-mentioned deepest ports are followed by the Visotsk port, which is 15.6 m deep and the Ust Luga port, which is 15.2 m deep. The available depth allows the deepest ports in the eastern Baltic Sea to handle the largest quantities of oil and oil products, as they can accommodate tankers with the largest draft.

In order to ensure economies of scale in global practice, the largest draft vessels are required to transport oil products and bulk cargoes, so these berths are usually the deepest. Figure 14 above illustrates that the depths at the quays of these ports on the eastern shores of the Baltic Sea are also the largest, thus, maximizing the available port depth. The ports of Tallinn (18 m), Ventspils (17.5 m) and Primorsk (17.8 m), which are one of the largest oil handling ports on the eastern coast of the Baltic Sea, have the largest depths at the liquid cargo berths.

The average draft of container vessels is smaller than the average draft of tankers or bulk carriers. Therefore, the depths in the Baltic Sea ports at these quays are shallower. The maximum possible draft of the Klaipeda port at the quays loading containers is 14.5 m and, in comparison with the competing ports, it corresponds to the general average.

Ro-Ro cargo berths are the shallowest. Due to the low weight of cargo, this type of vessels has a lower draft compared to other vessels. The ports of Ventspils and Tallinn have the deepest Ro-Ro berths. Meanwhile, even though it has shallower Ro-Ro quays compared to other competing ports, the port of Klaipeda, remains the leader in this type of cargo in the region.

Quays of the Klaipeda port, compared to all the ports of the Eastern Baltic region, are among the longest (26.8 km), lagging behind the port of St. Petersburg (21.8 km) only. Quays of Primorsk (20.3 km) are slightly shorter.

The analysis revealed that the ports of Klaipeda, Riga and St. Petersburg on the eastern Baltic coast have the most berths. The smallest ports are the ports of Visotsk and Primorsk, which specialize in one type of cargo transportation only (the port of Visotsk specializes in bulk cargo and the port of Primorsk—in oil and oil products). Other ports on the eastern Baltic coast handle bulk, liquid, Ro-Ro, containers and general cargo. The number of berths in the ports allows to handle almost all types of cargo. It should be mentioned that the port of Klaipeda cannot load coal due to environmental requirements. The general situation shows that the ports of the Eastern Baltic region have sufficiently adapted to today's competitive conditions and can offer a wide range of services. The key question, however, is whether they are making efficient use of their existing infrastructure.

The port of Riga has the largest open (1,894,278 m^2) and closed warehouses (418,603 m^2). The Klaipeda port also has a number of closed (99,380 m^2) and open warehouses (1,045,879 m^2) in the eastern Baltic Sea region. The ports of St. Petersburg and Tallinn also have a large area of open warehouses, but the total area of these ports is larger than the area of the port of Klaipeda. This shows that the Klaipeda port efficiently uses the available area by filling it with warehouses. The ports of Tallinn, Venspils and St. Petersburg have the largest tanks for liquid cargo and handle the largest volumes of oil.

3.2. Cargo Flows in Ports of the Eastern Baltic Coast

The volume of cargo handling in ports is an indicator, which describes the intensity of port activities and the result achieved after the implementation of public (port directorate's) and private (port operators') investments. Currently, regions of the eastern Baltic Sea are the fastest growing ports in the world. Many transport corridors cross the Baltic region. Corridor I is the most important for Lithuania. This corridor is important for all the three Baltic countries. The Northern Triangle and Corridor IX A are important for Finland. The Baltic Sea motorway, which is important for all ports, crosses the Baltic Sea.

In this case, the analysis of cargo flows includes the main ports of the eastern Baltic Sea: Ust Luga, Primorsk, St. Petersburg, Klaipeda port, Riga, Ventspils, Tallinn, Visotsk, Kaliningrad and Liepaja.

In 2020, the total cargo flow in the main ports on the eastern Baltic Sea coast amounted to 361 million tons, which decreased by 1.9 percent from 2015 to 2020. Figure 18 illustrates the overall dynamics of cargo flow in ports of the eastern coast of the Baltic Sea.

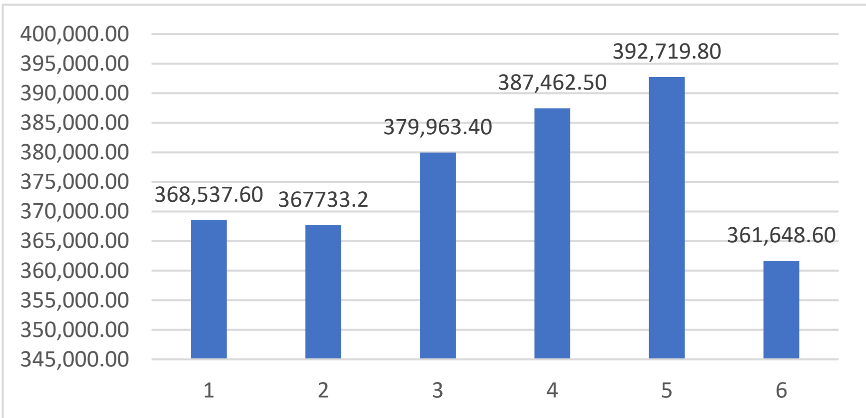

Figure 18. Total cargo flow in ports of the eastern coast of the Baltic Sea in 2015–2020 (thousand tons).

During the analyzed period, the total cargo flow steadily increased till 2019. However, comparing the total cargo flow in 2020 with that of 2015, a decrease of 1.9 percent was observed and compared to 2019; the total cargo handling in ports of the eastern coast of the Baltic Sea decreased by 7.9 percent.

Four ports can be distinguished in terms of volume of cargo handling: Ust Luga, Primorsk, St. Petersburg and Klaipeda. These ports have the largest volumes of cargo handling accounting for 66.6 percent of all the handling works.

Individual ports have different patterns of change in cargo flows. Different types of cargo are exported and imported in the ports of the Eastern Baltic Sea. In terms of handling (Figure 19), Russian ports of Ust Luga, Primorsk and St. Petersburg stand out of all the ports of the eastern coast of the Baltic Sea, as these ports carry out the largest stevedoring works in the Baltics. The port of Primorsk leads the region in the handling of oil products, but the handling of oil products is also growing rapidly in the port of Ust Luga. During 2019, the port of Ust Luga increased transhipment by 5.2 percent, achieving the result of

103.852 million tons. Although transhipment of oil products increased by five percent to 31.257 million tons, transhipment of oil decreased by five percent.

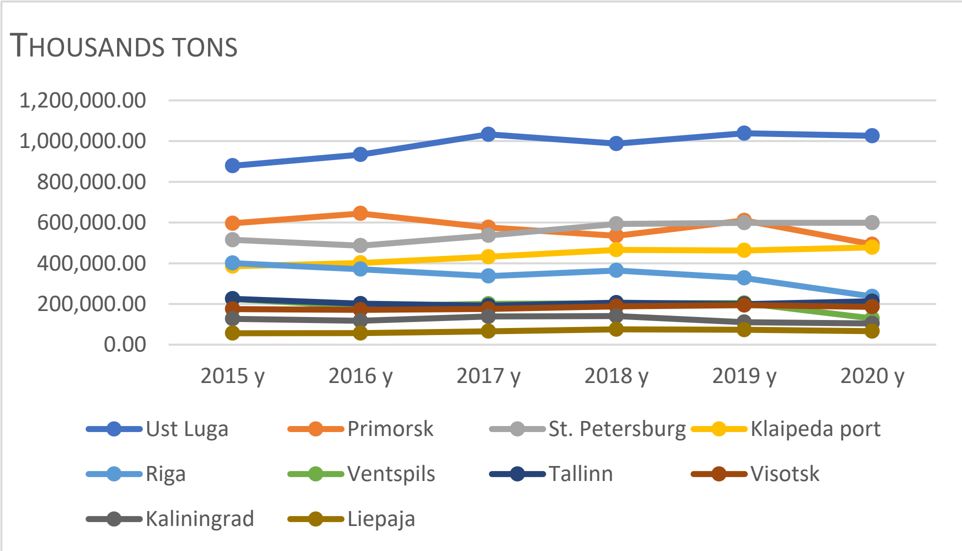

Figure 19. Cargo flow in separate ports of the eastern coast of the Baltic Sea in 2015–2020.

In 2015, the port of Riga ranked fourth in terms of volume of cargo handling, with 40,055.8 thousand tons. The port of Riga was the largest Latvian port in terms of cargo volume during the entire analyzed period.

Since 2016, the Klaipeda port ranked fourth and has maintained a strong position to this day.

Having exceeded 47 million tons of cargo turnover in 2020, the Klaipeda port has been the leader in terms of cargo volume among the ports of the Baltic States for the fifth consecutive year, ahead of Latvian and Estonian ports. Lithuanian and Belarusian cargo accounts for the major share of cargo at the Klaipeda seaport. The port also engages in redistribution, reloading cargo shipped by sea onto smaller ships, which carry cargo to other ports. We associate the growth perspective with the latter area the most. The Klaipeda port is a port handling the greatest variety of cargo types, from liquid, bulk cargo to gas. The Klaipeda port is a very versatile, multifunctional port, with no dominating type of cargo. Russia is the most important country for transit cargo in Latvian and Estonian seaports, while Belarus is becoming increasingly important at the Klaipeda port. Due to the favorable distance between Belarus and the Klaipeda port, transit cargo flows from Belarus should continue to be important in the cargo structure of the Klaipeda port. The ports of Klaipeda and Kaliningrad are the closest sea points to the Belarusian factories, while transportation time and costs also make them the cheapest. In recent years, the Klaipeda port has invested heavily in berths for handling bulk cargo—both fertilizers and agricultural products, leading to a record-high increase in the handling of bulk cargo to as much as 23.9 million tons. This also includes the handing of Belarusian fertilizers. In general, Belarusian cargo accounts for about a third of all handled freight in the Klaipeda port. In 2020, Belarusian cargo grew by about 10 percent in the Klaipeda port. The Klaipeda port also invests in the handling of general cargo, including container handling and liquid cargo handling complexes. Volumes of some cargo decreased due to changes in consumption related to COVID-19, while others increased, balancing out the total cargo handling at the Klaipeda port.

In Estonia, seaports play an important role in the cargo transport chain. Freight, which is usually carried by rail, is later carried by sea to the main ports. In 2017, 19.18 million tons of cargo and in 2020, 21.3 million tons of cargo were handled at the port of Tallinn. Export accounted for 30% of the total cargo and import for 17 percent. The comparison of cargo handling growth rates during the period from 2015 to 2017 revealed that cargo handling constantly decreased in Tallin (from 22,528,000 tons to 19,181,700 tons in 2017). In 2018, cargo handling went back up to 20.6 million tons, but in 2019, it decreased again to 19.9 million tons. In 2020, handling increased to 21.3 million tons and this was the largest volume of cargo in the port of Tallinn in the last five years. The port of Tallinn suffered significant losses due to COVID-19.

Meanwhile, the handling of Liepaja, Riga and Ventspils ports of our neighbor Latvia decreased significantly in 2020 compared to 2019 (cargo handling in Ventspils port was 20.45 million tons in 2019 and 12.9 million tons in 2020; in Riga port, 32.8 million tons of cargo were handled in 2019 and 23.7 million tons in 2020; in Liepaja port, 7.3 million tons of cargo were handled in 2019 and 6.6 million tons in 2020). Latvian ports and especially the port of Riga, received a lot of investment in recent years. A new coal handling complex with deep-water embankments was installed at the port. Nevertheless, coal and other oil products were among the cargo plunging the port of Riga, which handled a total of 23.7 million tons of cargo in 2020, which was as much as 22.7 percent less than in 2019. Russian coal and oil products made the port of Riga lose 8.8 million tons of cargo in 2020. When Russian cargo volumes decreased, the handling of Latvian products, mainly grain and timber, increased in the port of Riga and the port managed to maintain the same container handling volume. Cargo handling in the port of Ventspils dropped by as much as 36.9 percent to 12.9 million tons. The port lost as much as 73 percent of bulk cargo, which mainly was Russian coal. In addition, the handling of oil and oil products fell by 18 percent. With a huge deficit, various general cargo was loaded in the port of Ventspils, the volumes of which increased. The comparison of all Latvian ports revealed that cargo handling fell the least in the port of Liepaja by 10 percent. This port handled 6.6 million tons of cargo, with a drop in Russian coal volumes by as many as 74 percent. Unlike in the ports of Riga and Klaipeda, the port of Liepaja also handled slightly less grain and as much as 85 percent less diesel.

The growth in cargo handling in the port of Kaliningrad was recorded during the period from 2016 to 2018, when it was 14 million tons. In recent years, i.e., in 2019 and 2020, cargo handling in Kaliningrad ports decreased by 7.6 percent to 1.581 million tons.

It can be concluded in summary, that many ports on the eastern Baltic Sea coast handle different types of cargo, but they all have a specific type of cargo dominating in the port. The largest oil handling port is Primorsk, which is the main point of export of Russian oil. Oil handling capacities in this port increase every year and the Russian government's policy of handling all freight through Russian ports has a lot to do with that. In January–December 2020, the port of Primorsk handled 49,301,500 tons of cargo per year, which is 19 percent less than in 2019. According to the data of the Port Authority, crude oil handling decreased by 30% over the year and amounted to 33,208,800 tons, while the handling of oil products increased by 19 percent to 16,092,700 tons. In 2019, the port of Primorsk received 61,024,100 tons of cargo per year, which is 14 percent more than in 2018. This decision of the Russian authorities has affected other Baltic Sea ports. In 2020, the volume of oil handling decreased in all ports, except St. Petersburg, Ust Luga, Klaipeda and Kaliningrad (see Figure 20). In addition, to Primorsk, the other largest oil ports in the Baltic region were Ust Luga and St. Petersburg. It should be noted that the volumes of cargo in both Ust Luga and St. Petersburg increased significantly until 2019.

The port of St. Petersburg is the undisputed leader in container cargo. This port is the main gateway for container cargo to the Russian market, which continues to offer significant growth opportunities. Moreover, the plan is to reach the container handling of 3 million TEU in the port of Ust Luga in the near future and it will be the largest container port in Russia. Collectively, ports of the eastern Baltic Sea region handled about 3.7 million tons in 2020, while the port of St. Petersburg handled almost 58 percent of the total volume. The largest growth in container handling was in the port of Kaliningrad in 2018, where the number of containers increased by 16.5 percent.

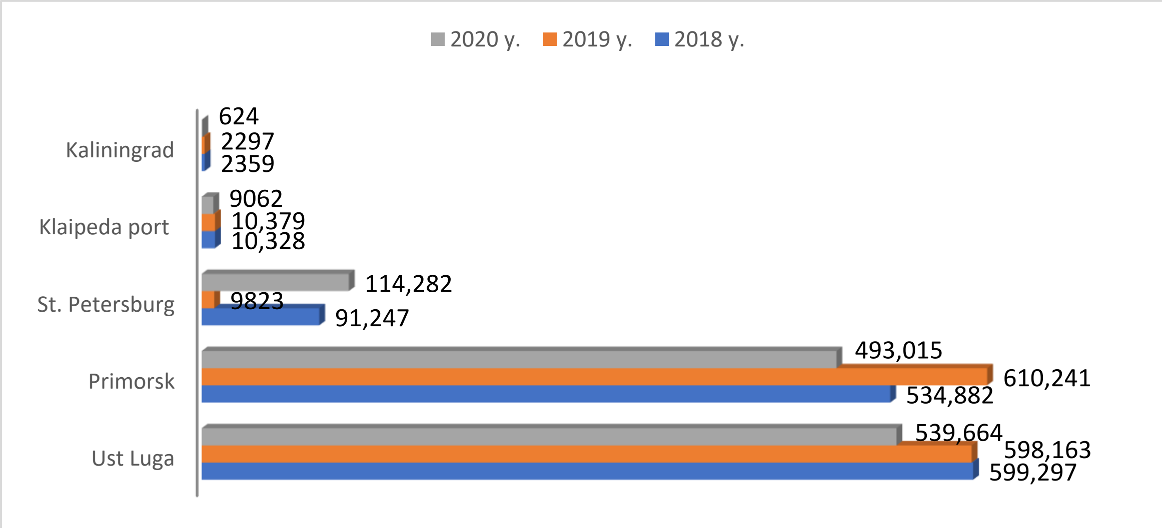

Figure 20. Largest oil handling ports in the Baltic region, thousand tons.

The sufficiently large jump in container handling was determined by the Kaliningrad port's investments in infrastructure and the opening of a new deep-water container terminal. The Klaipeda port also plays an important role in the container market. It is the second largest port in terms of container handling in the eastern Baltic Sea region following St. Petersburg. The Klaipeda port is followed by the port of Riga, Kaliningrad and the port of Tallinn, which ranks fifth. Figure 21 illustrates container handling in the ports of the eastern Baltic coast during the last 3 years.

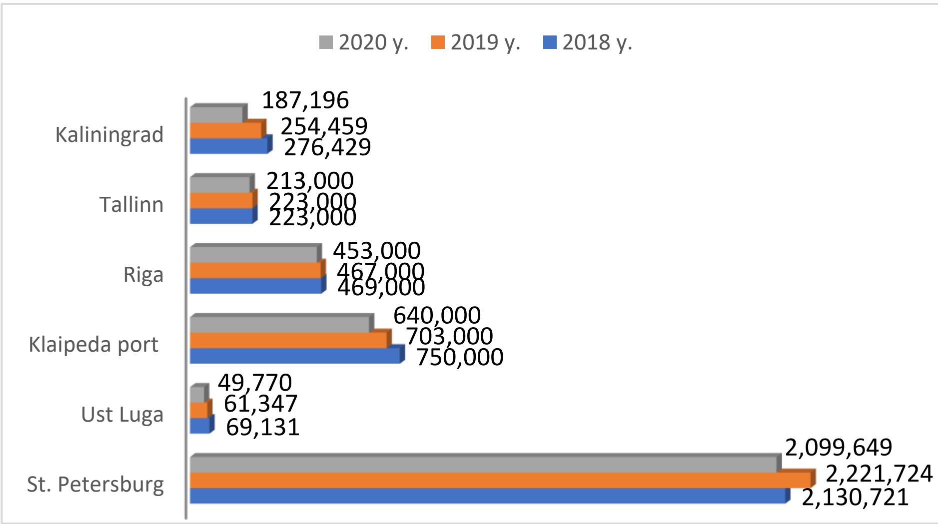

Figure 21. Container stevedoring ports in the Baltic region, TEU.

The Klaipeda port also handles the largest volumes of fertilizers (15.4 million tons in 2020). Transit cargo constitutes more than half of fertilizers loaded at the port. Belarus is the largest partner of the Klaipeda port, with more than 8.7 million tons of fertilizers coming from it. However, Belarusian cargo is highly dependent on the political situation and can be easily diverted via Latvian or Ukrainian ports.

The Klaipeda port is also the largest Ro-Ro port. Ro-Ro handling amounted to 307,000 pcs. in 2020, which is 5 percent more than cargo handling levels achieved in 2019. The Klaipeda port is in a suitable location for developing maritime connections with German ports. This is one of the reasons why the Klaipeda port leads in the Ro-Ro market.

The port of Ust Luga is the largest coal handling port—coal handling accounts for about 37 percent all stevedoring works of the port. In 2020, the port handled over 37,791,800 tons of such cargo. Russia is the main exporter of coal through the ports of the eastern Baltic region: Ust Luga, Visotsk, Kaliningrad and St. Petersburg. The Latvian port of Riga ranks second, having handled 2,653,300 tons of coal in 2020. The Klaipeda port cannot load coal due to environmental restrictions.

In 2020, grain handling grew rapidly in the port of Riga, which was 38.4 percent more than in 2019. Grain handling in Liepaja port makes up more than 14 percent of all cargo. A significant amount of grain produced in Lithuania has been transshipped through Latvian ports, as the Klaipeda port currently, does not have sufficient capacity. However, in the future, after the terminal operators improve the grain handling equipment and capacity, attracting grain freight to the Klaipeda port is expected.

It can be concluded, in summary, that the Klaipeda port is the most diversified port in the eastern Baltic Sea region, which does not have one most important cargo type. The largest bulk ports are in Tallinn, Riga and Ventspils. The largest port for liquid cargo is Primorsk and St. Petersburg handles the greatest volumes of general cargo.

3.3. Results of Correlation between Cargo Flows and the Selected Port Infrastructure Parameters

Seaports are an indicator of a country's economy. Research of the transported cargo, i.e., their quantitative scale and composition, allows determining changes in the country's economy. Global practice shows that solely countries with well-developed transport infrastructure and different modes of transport have achieved a high level of economy and well-being of their citizens. The transport policy developed in such countries is closely linked to the country's economic and political stability. Cargo flows in all modes of transport depend on political and economic considerations and the geographical location. Ports of the Baltic Sea have been divided into regions according to their geographical location and the geographical location also allows to describe ports according to the seasonality of their work and the uniqueness of climatic conditions of their operations. Most importantly, however, the geographical location allows us to assess the connectivity of seaports with logistics systems, other modes of transport and integration into European and Asian transport corridors. The analysis of ports on the eastern Baltic coast first of all aimed to assess the distribution of cargo flows (see Figure 22).

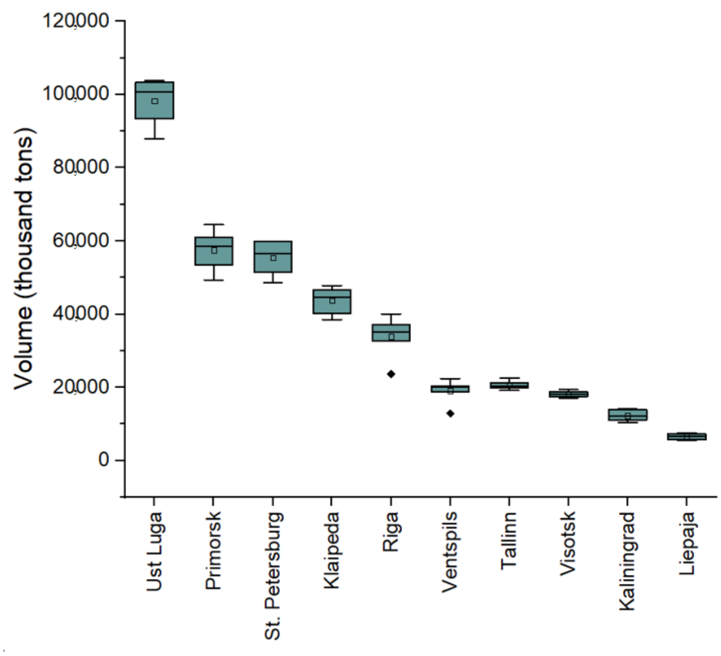

Figure 22. Distribution of cargo flows in ports of the eastern Baltic coast in 2015–2020.

The results (Figure 22) illustrate that the ports of Visotsk and Liepaja have the best distribution of cargo flows. However, statistical data of ports of Riga and Ventspils are unacceptable in terms of the overall distribution of the quantile field in terms of reliability, which is clearly visible in the part of the graph illustrating the pandemic period, i.e., it clearly shows the elongation of the quantile field. Therefore, in the assessment of these indicators, it was important to assess how this distribution changed before (see Figure 23) and during the COVID-19 pandemic (see Figure 24) and whether this affected the distribution of cargo flows in ports.

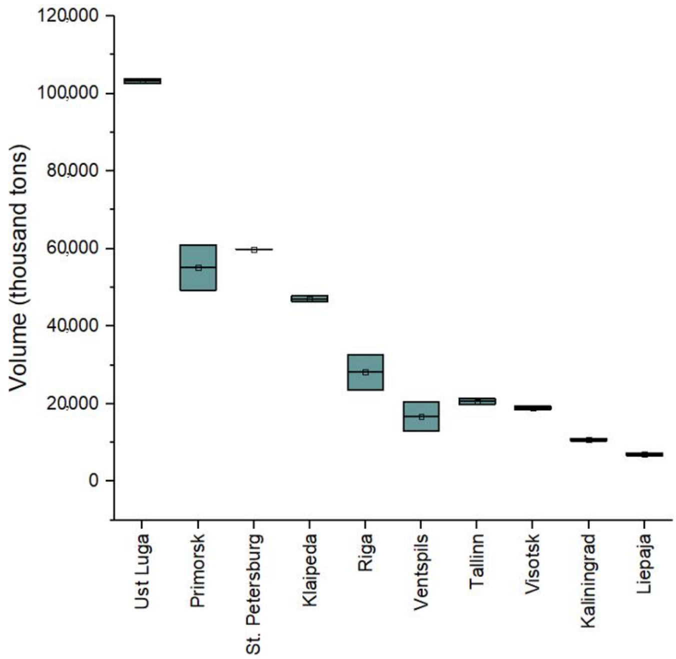

Figure 23. Distribution of cargo flows in ports of the eastern Baltic coast in 2015–2019 (before the COVID-19 pandemic).

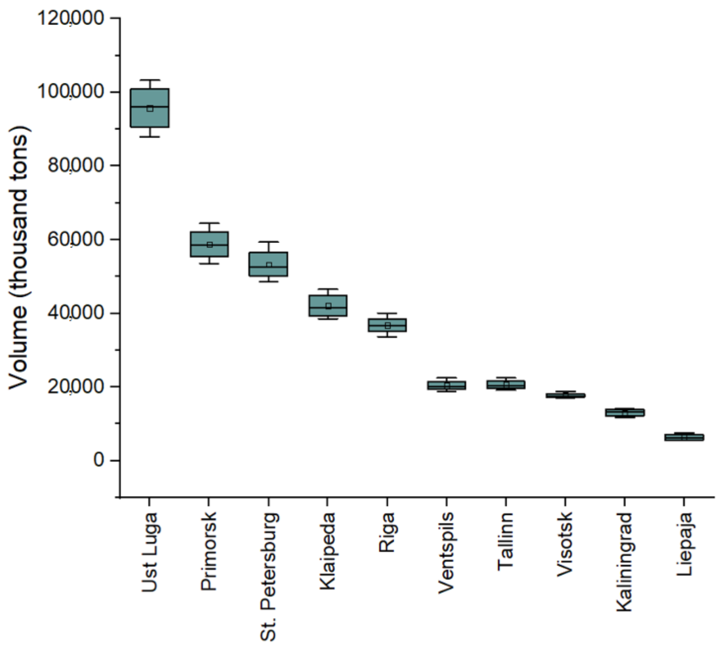

Figure 24. Distribution of cargo flows in ports of the eastern Baltic coast in 2019–2020 (during the COVID-19 pandemic).

Before the pandemic, a more even distribution of cargo was observed in five ports: the ports of Visotsk, Liepaja, Kaliningrad, Tallinn and Ventspils. However, the results of the pandemic period (see Figure 24) showed a slightly different situation.

Quantum fields shrank during the pandemic period, while the ports of Riga, Ventspils and Ust Luga maintained similar trends, which possibly may be due to political decisions of Russia and Belarus to divert cargo to other ports. As a result, the port of Riga suffered due to a major loss of coal and oil cargoes. The port handled a total of 23.7 million tons of cargo in 2020, which was 22.7 percent less than in 2019. In 2020, the port of Riga lost 8.8 million tons of Russian coal and oil products. Cargo handling in Ventspils port dropped by 36.9 percent to 12.9 million tons. The port lost 73 percent of bulk cargo, which mainly was Russian coal and handled 18 percent less oil and oil products.

In light of the above, the further analysis sought to assess whether the infrastructure of the ports under consideration was used to the maximum in terms of cargo flows. In summary, it can be concluded that: (1) of all the ports, the port of Visotsk has made the best use of its infrastructure; (2) the COVID-19 pandemic and the received results allowed eliminating economic and geographic factors and highlighted the political motives, which had an obvious impact on the dynamics of cargo distribution. In view of the results received and the dynamics of cargo distribution, as well as the expected growth of cargo flows, it is very important to determine which of the ports under consideration made the best use of their infrastructure in terms of cargo flows (see Figure 25).

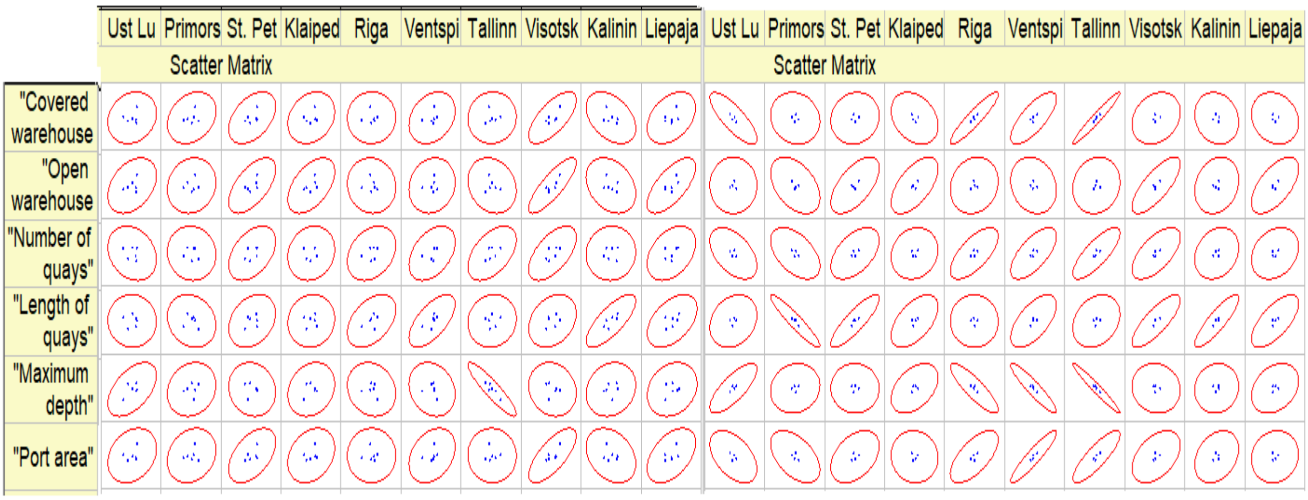

Figure 25. Correlation between cargo flows and the selected port infrastructure parameters (aggregate indicators are presented on the left and indicators before the COVID-19 pandemic—On the right).

The correlation between cargo flows and the selected port infrastructure parameters revealed that:

1. In general (in terms of aggregates) the best use has been made of: (1) the maximum depth—in the port of Tallinn; (2) the length of quays—in the port of Kaliningrad. In general, however, the port of Visotsk looks best in terms of all the parameters. The correlation results show that the port of Visotsk is approaching the maximum use of its infrastructure capacity. Other parameters selected for the analysis do not correlate significantly with the distribution of cargo flows, which means that the available infrastructure capacity of the ports has not been used to the maximum.
2. Before the pandemic, the best use has been made of: (1) covered warehouses (the ports of Ust Luga, Riga, Ventspils and Tallinn); (2) open warehouses (the port of Visotsk); (3) the number of quays (the ports of Tallinn, Ventspils, Visotsk and Riga); (4) the length of quays (the ports of Primorsk, St. Petersburg, Kaliningrad, Visotsk

and Liepaja); (5) the maximum depth (the ports of Tallinn, Ventspils, Riga and Ust Luga); (6) the port area (the ports of Ventspils and Tallinn).

There were insufficient data to analyze the pandemic period.

4. Conclusions

In Lithuania, the Klaipeda port is the main transport hub of the country and Lithuania's gateway to the world. The Klaipeda port is the only Lithuanian seaport located in the southeast of the Baltic Sea, at the mouth of the Curonian Lagoon. It is one of the leading ports of the Baltic Sea, characterized by intermodal transport opportunities, integration into the TEN-T railway corridor, as a result of which the two main railway lines connect the port with neighboring countries and the internal territory of Lithuania. It is also the northernmost non-freezing deep-sea port on the eastern coast of the Baltic Sea.

There are three main seaports in Latvia: ports of Riga, Ventspils and Liepaja. In order to strengthen the position of the ports, they have been provided with favorable business conditions, for example, giving them 80–100% discounts on direct and indirect taxes. The ports of Riga and Ventspils are independent, while the port of Liepaja forms a free economic zone together with the city. In the port of Riga, two main raw materials, namely, coal and oil, account for the major share of freight. Traditionally, the vast majority of coal and oil has reached the port of Riga in transit from Russia. The fact that the Klaipeda port does not have the possibility to load coal also has a significant impact on the port of Riga. The port of Ventspils is the largest oil handling port in Latvia. In addition to oil, the port of Ventspils also loads coal. In general, coal and oil dominate in the Latvian ports, the largest quantities of which come from Russia. Therefore, the volume and prospects of cargo handling in Latvian ports are highly dependent on the Russian economy, its trading partners and the political relations between the two countries.

In Estonia, seaports also play an important role in the cargo carriage chain. Usually, freight carried by rail to major ports is later transported by sea. Estonian ports handle oil and Ro-Ro cargo.

Although the Russian maritime transport sector has not been developed for a long time, it is now the most developed mode of transport. In 2007, the port of Ust Luga started operating in Russia. Currently, it is the main loading port among the ports on the eastern coast of the Baltic Sea. There are currently 11 terminals operating in the port. In addition, the Russian government has decided to carry the greatest possible volumes of Russian cargo via its own ports rather than using services of other countries. In the future, this should lead to an even greater impact of Russian ports on the eastern Baltic Sea region, as a large part of Russian cargo is currently carried through the Baltic ports. The most important Russian port on the eastern coast of the Baltic Sea is the port of Ust Luga, with crude oil, oil products and coal accounting for the greatest share of cargo handled there. The second most important Russian port is the port of Primorsk. This port only handles oil and oil products, which Russian oil companies carry via pipelines. The third most important port on the east coast of Russia is St. Petersburg. It is the largest container port on the eastern coast of the Baltic Sea. The ports of Primorsk and Ust Luga are the main ports for oil exports from Russia and the port of St. Petersburg is the main port for imported cargo (mainly containers).

The above information allows to model the directions of further research in the following two stages: (1) changes in cargo flows and their impact on economies of the countries taking into account political decisions of Russia and Belarus; (2) the impact of COVID-19 on cargo flows and port competitiveness.

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