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ANALYSIS AND ASSESSMENT OF LOGISTIC CAPACITIES OF POLAND'S LARGEST SEAPORTS IN TERMS OF MANAGEMENT

Abstract: *One of the key factors for competitiveness in the international maritime sector, and for the quality of service and acquisition of new clients for seaport services, is the logistic capacity of seaports, which requires continuous development of seaport infrastructure. The need to respond to the growing demand related to the increasing volume of cargo handling in seaports leads to improved capacity and accessibility of the seaport infrastructure and suprastructure. The purpose of this paper is to determine the role and position of Polish seaports in the supply chains on international trade markets. The study included major Polish multipurpose seaports - Port of Gdansk, Port of Gdynia, and Szczecin and Swinoujscie Seaports. The following statistical tests were used in the study: Mann-Whitney U test for comparing two groups, and Kruskal-Wallis test by rank for comparing more than two groups. The analysis of correlation between two numeric variables was performed using Spearman's rank correlation coefficient; the significance of Spearman's correlation was tested using the t-test. The results of the study provide a classification of Polish seaports which play a crucial role for Poland's national economy. The obtained results indicate that the volumes of container handling in the Polish seaports increased in the analysed period, i.e. the value of handling grew with time. This classification makes it possible to specify the advantages and disadvantages of the analysed seaports, and to determine the profile of their operations.*

Keywords: *Seaports, Logistic Capacity, Infrastructure, Cargo Handling*

1. Introduction

As hubs linking maritime and land transport, seaports are indispensable elements of supply chains, equipped withorganisational, technical and production means to provide a whole range of transport, logistic and marketing services. Due to their functions and broad scope of operations, seaports are essential for the global supply chains (Klimek & Dąbrowski, 2017). J. Witkowski (2003) considers logistics operators and shipping companies to be the most active actors in the logistic chain, as their services span across various links of the chain, playing an important role in cargo transport and storage, and for the accompanying flow of information and money between subsequent stages of manufacturing and trade. By

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working together with other supply chain stakeholders, seaports create added-value chain for the end client and for themselves (Grzelakowaki, Matczak, 2009; Pileggi et al.2020).

Following their Development Strategies to 2027 (harmonised with all development strategies of other Polish and European ports), the analysed seaports are improving the standards of their services and reinforcing their market positions as efficient logistic hubs for the Baltic Sea, the North Sea and the Far East.

Poland's government is supporting the development of the national seaports due to the significance of maritime transport and its infrastructure for international trade. For this purpose, the Ministry of Maritime Economy and Inland Navigation launched the Program for the development of Polish seaports to 2020 (with a perspective to 2030), an operational and implementation document under the Strategy for Responsible Development to 2020 (with a perspective to 2030), and the Transport Development Strategy to 2020 (with a perspective to 2030), according to the relevant development policy principles (EU strategy for transport and seaports - White Book, Blue Belt) (Ministry of Maritime, 2018).

In September 2019, the Polish Sejm passed a resolution on adopting the program under an updated name "Program for the development of Polish seaports to 2030"; the total investment expenditures were estimated at PLN 40 billion. Polish seaports play an important role in the national economy, generating a significant portion of the state budget revenue (from customs and taxes) - in 2018, the seaports generated a revenue of PLN 40.6, as compared to PLN 17.7 billion in 2015. The development strategy estimates the cargo handling to grow to 150 million tonnes by 2030. Between 2013 and 2016, the volume handled was around 70 million tonnes, and from 2016 to 2018, it grew past 90 million tonnes (including the total weight of handling units) and amounted to more than 100 million tonnes. The priorities of the adopted strategy included major investments in Polish seaports:

- Port of Gdansk - construction of the Central Port,
- Port of Gdynia - construction of the Outer Port and the new Intermodal Rail Terminal in the Inner Port,
- Szczecin and Swinoujscie Seaports - construction of the Container Terminal (Swinoujscie), and deepening of the fairway on the Oder river between Szczecin and Swinoujscie to the technical depth of 12.5 m (www.gov.pl, 2019).

Poland's largest seaports are logistic hubs of regional or international importance, depending largely on the development of the inner port, as well as location and accessibility. Those factors determine the port's availability and thus its market position (Verhoeven, 2010).

Logistic operations in seaports are crucial for the performance and efficiency of maritime and land transport. The purpose of this study is to assess the logistic capacity of seaports using methods from the domain of management and applied logistics, in order to conduct a comparative analysis of the discussed seaports in this respect.

2. Main heading

Maritime transport plays an essential role in the global economy, emphasising the importance of the land and maritime transport routes. Similarly, to other modes of transport, maritime transport infrastructure is divided into linear infrastructure and nodal infrastructure. The former includes all open maritime routes with technical as well as signalling and navigation components ensuring efficient transport of passengers and cargo. The nodal infrastructure includes mainly seaports with complex organisational structure making the port's services and functions available to the supply chain participants (Wojewódzka-Król, Załoga

2016; Monios, 2017).

The seaports have specific infrastructure for handling specific types of cargo and processing specific types of ships, which can be categorised as follows:

- infrastructure with uninterrupted (pipeline) workflow, e.g. pipelines, pneumatic machinery, belt conveyors, silos, etc., and infrastructure with periodical workflow, e.g. overhead cranes, harbour cranes and truck-mounted cranes, and lifts;
- special-purpose equipment (for specific types of cargo), e.g. coal conveyors, and multipurpose equipment (for various types of cargo), e.g. piece goods cranes;
- stationary and mobile equipment;
- ship- or harbour-specific equipment (Kozerska, Krzywda, 2018).

In economic terms, seaports should be considered central nodes where the supply of and the demand for the offered port services meet. Through purchase and sales of the available services, the port services market is created. The rules of the market, the mutual relations between the elements of the port services market (supply, demand, prices), and the entities participating in trade (port users, service providers) create a specific spatial and transport environment between the seaports and the manufacturing centres in the port hinterland (Rucińska, 2015).

W. Rydzykowski and K. Wojewódzka-Król (2008) define the quality of port services as three S: Safety, Speed and Sureness (Baird, 2004).

The value of port services as a means to meet the consumers' needs can be measured in qualitative (functional) terms and by the qualities of the service provider, i.e. speed, scope, availability, security, reliability and environmental friendliness (Grzelakowski, Matczak, 2006; Czermański et al., 2022). The port service quality can be categorised by specific vectors:

- vector of offered properties - expresses the quality of the service as defined subjectively by the service provider (i.e. cannot be used as a quality vector) in terms of the degree of usability (Misztal, 2010; Da Cruz et al. 2013),
- vector of desired properties - the quality of service as expected by the consumer, describing the prominence of the given feature in the set; due to its subjective nature, it cannot be used to objectively define the quality of the services (Karaszewski, 2009).

H. Klimek (2008) presents a classification of economic functions by dividing them into two basic groups:

1) Subject Functions- which include the following functions: transportation,
   logistics and distribution, trade, industry and travel service;
2) Spatial functions- city-forming, region-forming and regional functions.
   The first function - transport - plays a key role, aiming to satisfy the diversity of services with respect to passengers, cargo, and maritime/land transport elements (e. g. berthing, fuel supply and emergency services).

According to L. Kluźma (2003), the economic factor conditioning the development of the transport function of the port is the demand for its reloading and storage services. Demand efficiency is determined by transportation accessibility (technical and economic) and inter-port competition. This involves the concentration of capital and port potential, specialization and the creation of vertical capital ties between ports and other participants in the port trade (. . .) thanks to which capital is strengthened, new customers are acquired and other economic functions are developed.

The logistic-distribution function according to M. Christowa-Dobrowolska (2007) results

from the following functions: transport, commercial and industrial, is associated with multifaceted services to the cargo; its flow through transport operations, distribution, trade, inventory management and logistical support.

As M. Adamowicz (2017) points out, "port services are considered to be the effect and product of economic activity of entities operating in the port and are provided directly or indirectly to cargo and passengers in connection with the need to change the means of transport from land to sea or vice versa". This process requires a multifunctional foundation of the entire port infrastructure in order to properly perform the port service while maintaining the safety of cargo movement through the port area.

In economic terms, seaports should be considered as focal points, the meeting of supply and demand for the port services offered. The market for port services is then created through buy-sell transactions of available services. Functioning principles, mutual relations of port services market elements (supply, demand, price) and entities participating in trade exchange (port users, service producers) create a spatial and transport scheme between ports and production centers located in the port's hinterland (Rucińska, 2015).

In the literature, supply and demand at the level of port services markets are systematized as follows:

- effective demand - "revealed" in a given time needs requiring the implementation of appropriate transport operations in the sea port, with precisely defined in terms of the object, scope, costs necessary to carry out the transport process by sea and land;
- potential supply - "measured" in terms of the current capacity of a given port operator or port, where a certain number of effective demand units (revealed needs) has been assigned (Grzelakowski, Matczak, 2012)

In consideration whereof and according to H. Klimek (2008) (figure 1), the higher the compatibility of specific offered properties with the desired properties, the higher the value of the overall quality of service; the balance between the vectors is illustrated on the figure below. The quality of service is evaluated when the functional properties of the service offered by the provider, are confronted with the properties expected by the consumer.

Port services are a "product" provided in the seaport by businesses to recipients and including a broad range of multiplatform economic activities based on the supply and demand for such services.

Constructive and systematic management of a seaport may determine its successful competitive ability in the international market.

As a result of the intense changes occurring in port environment over the last decades, new models of competitiveness have been developed, where port authorities try to increase their attractiveness. In this context, one of the most debated issues in this area of research is still the role played by port authorities in defining port competitiveness (Martinez Moya et al.2017)

In the port practice in Western Europe, you can meet both strategies of expansion into new ones port areas, as well as diversification strategies for previously developed areas. In most cases, therefore, we can speak of a location greater emphasis on acquiring new land for developing economic functions or for the revitalization of economically decaying port areas. It also happens that with revitalization the economically decaying port area requires the development of new ones plots in its vicinity (e.g. for logistics and distribution activities). In the period after the start of the systemic transformation, it was dominant in Polish seaports the strategy for the development of the port space was to revitalize the previously used port areas port

areas. The revitalization processes observed in Polish seaports are similar as was the case in Western European seaports, they followed in the analyzed period in two directions, i.e. transformations based on other port functions or as part of a given port function (an example of the universalisation of the transshipment offer) and based on the city and port functions (Pluciński, 2014; Yildiz et al.2010).

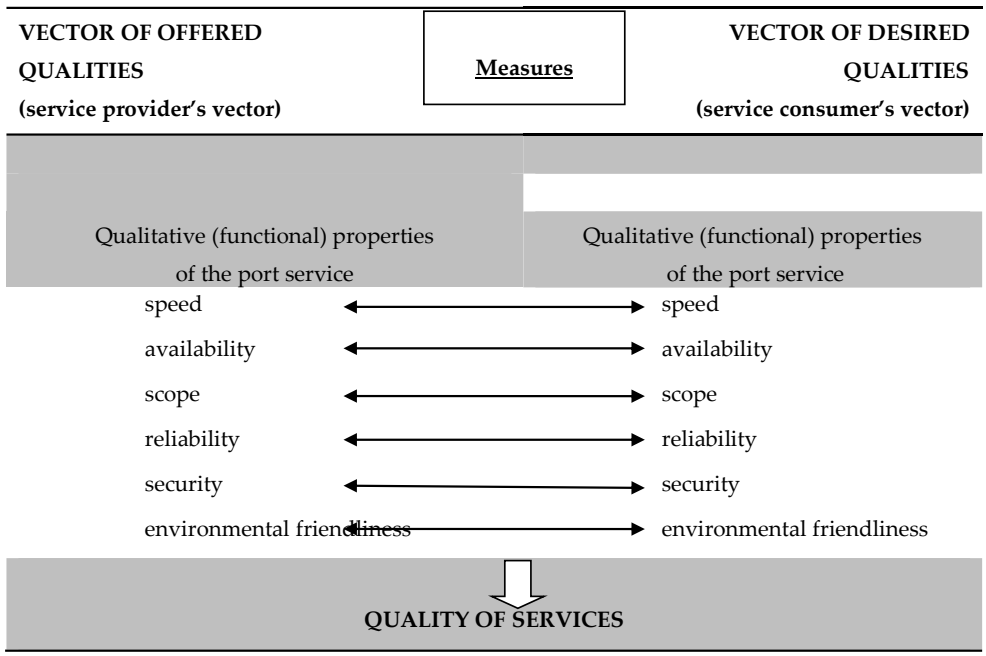

Figure 1. Functional properties and measures

Poland's largest seaports

The Port of Gdansk is located in the southern part of the Baltic Sea coast, in the northern part of Poland. It is an important link in the trans-European transport corridor no. I. connecting the Scandinavian countries with South-Eastern Europe. In 1998, the Port of Gdansk was transformed into a commercial law company. Port of Gdansk Authority S.A. operates on the basis of the Code of Commercial Companies and the Act on Sea Ports and Harbors. The company is the only one to manage the port, which includes: providing ships with access to waste reception facilities, management of port infrastructure, provision of services related to the use of port infrastructure, port development planning, property management, modernization and construction of new port infrastructure and acquisition of land for development port(Kozerska, Krzywda, 2018).

The area of the port of Gdansk is 679 ha, and the total length of the port infrastructure is 23.9 km, the storage area of 105,530 m2 and a storage area of 1,456,623 m3 (silos and elevators 68,000 tons) should also be distinguished. The port area is divided into technologically specialized activities in terminals and quays, related to the service of various cargo groups, such as: general cargo, containers, ro-ro, coal, liquid fuels, other bulk cargo(Kozerska, Krzywda, 2018; Ministry of Maritime, 2018).

The Port of Gdynia is located in the northern part of Poland, in the central part of the southern coast of the Baltic Sea. It is a modern universal port, specializing in handling general cargo, mainly unitized, transported in

containers and in the ro-ro system. according to an extensive network of multimodal connections with the hinterland, regular short sea shipping lines and ferry connections. The port in Gdynia is an important link in the 6th Corridor of the Trans-European Transport Network TEN-T(Kozerska, Krzywda, 2018; Salomon, 2017).

The Port of Szczecin-Swinoujscie is the westernmost Polish port complex, located in the north-western part of Poland. The Port of Swinoujscie and the Port of Szczecin form one of the largest port complexes in the Baltic Sea region. The port in Swinoujscie is located directly by the sea, and the port of Szczecin is 65 km inland. The crossing from the road in Swinoujscie to Szczecin by the fairway takes about 4 hours. The location of these ports makes them complementary to each other. because thanks to the location of the port in Swinoujscie right by the sea, it can offer access to ships with a draft of up to 13.2 m. On the other hand, the port of Szczecin, which is 68 km away from the sea and it is also possible to call ships with a draft of up to 9.15 in it, is located at the mouth of the Odra River. which makes it the only Polish seaport with access to inland navigation, which is one of its undeniable advantages. These ports are the closest seaports for the south-western and western part of Poland(Kozerska, Krzywda, 2018; Ministry of Maritime, 2018; Salomon, 2017).

Competitiveness of Polish seaports

Due to their location, the main competition for Polish seaports are the ports of the southern and eastern Baltic, i.e. Lübeck, Rostock, Klaipeda, Ventspils and Riga. All these ports have similar limitations related to accessibility from the foreground (limitations of the size of ships entering the Baltic Sea) and a similar hinterland area. With regard to some cargo groups, other ports also compete with Polish seaports, i.e .:

- for dry and liquid bulk cargo - Ust-Luga, Vysotsk, Primorsk;
- for containerized cargo - Rotterdam, Antwerp, Hamburg, Bremerhaven;
- for ro-ro cargo - Sassnitz.

Characteristics of the basic parameters of ports

Polish seaports are fully universal ports. The share of bulk cargo in transhipment amounts to approximately 50% in the ports of Swinoujscie and Gdynia (a similar share is in Rostock) and approximately 65-70% in Szczecin and Gdansk. The two largest terminals that operate in the port in Swinoujscie are: the so-called a commercial port (currently: OT Port Swinoujscie) serving mainly bulk cargo and a ferry terminal, to which the port owes a significant share of general cargo. In practice, however, Swinoujscie handles negligible amounts of containers and significant amounts of ro-ro cargo. Major changes took place in the port of Gdansk. Until recently, Gdansk specialized in reloading of bulk cargo (in 2007, the share of bulk cargo in total reloading reached 90%). Currently, thanks to the construction and operation of the DCT terminal, the share of general cargo has increased several times. The Port of Latvia, although referred to as universal ports, mainly handle bulk cargo (share of bulk cargo: approx. 90% Ventspils, over 80% Riga). In addition to the loads of Polish foreign trade, they handle significant amounts of cargo from Russia and the CIS. The port in Lübeck serves as a groupage port, most of the cargo is transhipped in the ro-ro technology (Ministry of Maritime, 2018).

The basic parameters of the ports, such as: the area in which the port is located and the length of the quays, primarily testify to the degree of infrastructure development and show the port's development opportunities through the use of land reserves. The Latvian seasons Ventspils and Riga as well as the port of Gdansk have the largest land area. The port's storage area also shows, to some extent, the port's handling capacity. Lübeck and Riga have the largest storage area, both covered and uncovered, significantly larger than the other tested ports. The large storage area in the port of Lübeck, despite relatively small transshipments compared to other examined ports, results from the structure of the cargo

handled, which are mostly cargo reloaded in the ro-ro technology. This type of cargo requires significant storage areas due to the lack of possibility of stacking (except for paper). In addition to the above-mentioned ports, the ports in Gdansk and Klaipeda have a significant uncovered storage area, exceeding 100 ha. Among the analyzed ports, the Swinoujscie port has the smallest component area. The ports of Riga and Gdynia also have a significant covered area.

Characteristics of the port access infrastructure

The level of port accessibility from the sea depends on two important factors of port competitiveness, which are particularly important from the shipowner's point of view, i.e. the time of the ship's entry into the port and the permissible parameters of the ship. Almost all tested ports are located close to the open sea, which means that the time of entry to the port is relatively short. These ports are most often located directly at the mouths of rivers (Riga, Ventspils, Gdansk, Rostock, Lübeck) or, as in the case of Klaipeda and Swinoujscie, in the strait. Ports such as Ventspils, Swinoujscie and Gdansk also have external terminals directly above the sea. The exception is the port of Szczecin, which is located approx. 68 km from the open sea. This makes the entry (reaching) time to the port approximately 4 hours. However, this means physical proximity of the port to the hinterland and, as a result, limitation of the road section of the multi-link transport process, which means both the reduction of external costs of transport and the negative impact on the environment. The best conditions in terms of permissible parameters of ships are offered by the ports in Gdansk, Riga and Ventspils, serviced the largest ships entering the Baltic Sea. This applies to ships carrying both dry and liquid bulk cargo. The advantage of Gdansk is the possibility of handling container ships with a draft of up to 15.0 m. The ports of Gdynia, Swinoujscie, Klaipeda and Rostock have similar depth parameters and can handle ships of similar size. The ports of Szczecin and Lübeck have the worst parameters. While in Lübeck, due to the nature of the ships handled (mainly horizontal loading ships, not requiring significant depths), it is sufficient, for Szczecin - a port where the vast majority of transhipments are bulk cargo, it significantly weakens its competitive position. The factor that weakens the competitiveness of the port of Gdynia is the lack of sufficient parameters of the internal turntable and the appropriate depth to service the largest container vessels, due to the fact that the existing container terminals are located inside the port (Ministry of Maritime, 2018).

3. Materials and methods

The numeric variables were characterised by numerousness (N), standard deviation (SD), minimum value, the value of the first quartile (Q1) value, below which 25.0% of all observations are located, the median - the value below which 50.0% of observations are located, the third quartile (Q3), below which 75.0% of observations are located, and the maximum value.

In the analyses comparing the distribution of the numeric (or ordinal) variable between the groups set by the nominal variable, the following statistical tests were used: Mann-Whitney U test for comparing two groups, and Kruskal-Wallis test by rank for comparing more than two groups (Corder & Foreman, 2009).

The Mann-Whitney U test was used to test the zero hypothesis of the symmetry of probabilities related to the values of the variable in one of the analysed groups being higher than the values in the second group, i.e. $P(X > Y) = P(Y > X)$. Therefore, the statistically significant result of this test indicates that the values of the given variable in one of the groups are higher than in the other one. Similarly, for the Kruskal-Wallis test by rank, a significant result indicates that we can conclude that in at least one of the groups in consideration, the values of the given variable are significantly higher than in

the other one.

Where the Kruskal-Wallis test was used, the Dunn-Bonferroni post hoc analysis was performed in order to determine which groups differed significantly from one another.

The analysis of correlation between two numeric variables was performed using Spearman's rank correlation coefficient; the significance of Spearman's correlation was tested using the t-test. The value of the coefficient that is significantly higher than zero indicates a monotonic relationship between the variables. When it is higher than zero, we can infer that an increase of the value of one variable will be accompanied by an increase of the value of the second one. Similarly, if the Spearman's rank relation coefficient is below zero, the increase of the value of one of the analysed variables translates into a reduction of value of the other variable. The strength of the relation is proportional to the coefficient's absolute value approaching 1. The statistical significance level for this study was 0.05. All calculations and diagrams were made in R software (release 3.6.0) (Core Team, 2017).

Using a simplified model of hypothetical-deductive reasoning, the information on the unit processes should be gathered and the research problem should be formulated. Next, the hypothesis should be formulated and then confirmed in full or in part in the final stage (Lisiński, 2016).

Furthermore, the following limitations were specified for the research process: (Wood et al 2008):

- the research field is limited to Polish seaports due to the availability of the necessary statistical data;
- the statistical data refer to the years from 2008 to 2018.
  In order to solve the research problem, a number of research tasks were performed:
- review of specialised literature on seaports and logistic capacity thereof;
- choice of the method of evaluating the logistic capacity of the analysed seaports;
- evaluation of the logistic capacity using the chosen method;
- comparative analysis of the logistic capacities of seaports - conclusions and recommendations.

In this study, the following hypothesis is formulated: the model of hypothetical-deductive reasoning, usually applied to measuring the logistic capacity of seaports, may be an efficient tool to categorise seaports in terms of operational and systemic competitiveness, service quality and versatility in specific marine operations.

Seaports play an important role in integrating various modes of transport, providing a broad range of services involving cargo and seagoing vessels. Seaports are also important logistic hubs for the global trade (Verhoeven, 2010). The capacities of seaports can be measured using the appropriate methods from the field of management.

Considering the location of Poland's major seaports, their direct competitors are the seaports located on the southern shores of the Baltic Sea, i.e. Lübeck, Rostock, Kaliningrad and Klaipėda. Furthermore, in terms of the types of cargo groups handled, i.e. dry and liquid bulk cargo, Polish seaports compete with the ports in Riga, Tallinn, Primorsk, Ust-Luga and Ventspils, and in terms of container cargo, with Rotterdam, Antwerp, Hamburg and Bremerhaven (Wood et al. 2008).

For the seaports which are of major importance for Poland's economy, having specialised cargo handling piers is essential for attracting demand. Polish seaports have the following container handling terminals:

Port of Gdansk - DCT (Deepwater Container Terminal) and Gdanski Terminal Kontenerowy S.A.;

Port of Gdynia - BCT (Baltic Container Terminal) and GCT (Gdynia Container Terminal);

Szczecin and Swinoujscie Seaports - DB Port Szczecin (Motowidlak, 2013; Mańkowska et al. 2020).

The Deepwater Container Terminal in Gdansk has taken the container market on the Baltic Sea by storm, becoming the first container hub east of Denmark capable of handling large ocean-going vessels, processing cargo in transit to Russia and Finland and able to compete with the seaports on the North Sea, mainly the German ones. Dubbed the future "gateway for the Central and Eastern Europe", the DCT has a better location than the German seaports. In 2010, the Gdansk seaport took over some cargo handling from Hamburg, causing a drop in container handling volume in the latter). The reason for building the container hub in the DCT in Gdansk was the cooperation with Maersk which started in 2010 on the AE10 Westbound/Eastbound Route, with ocean-going vessels carrying 8,000 TEU from the Far East calling at Gdansk once a week (route: Ningbo - Shanghai - Kaohsiung - Yantian - Hongkong - Tanjung Pelepas - Le Havre - Zeebrugge - Hamburg - Gdansk - Gothenburg - Aarhus - Bremerhaven - Rotterdam - Singapore - Hongkong - Kobe - Nagoya - Shimizu - Yokohama - Ningbo) (Review of Maritime Transport, 2019). The next connections were the F15 Gdansk Finnish Gulf Service (Gdansk - Helsinki - Kotoka - Gdansk) and the F20 Gdansk - St Petersburg Shuttle. After reaching the container hub, the cargo is loaded on feeder vessels and transported to other seaports on the Baltic Sea (transhipment accounts for around 50% of DCT turnover). Between 1979 and 2009, Port of Gdynia was the leader in the volume of containers shipped. Following the rapid changes of 2010, Port of Gdansk took over the leading position (Klimek, 2016). The DCT's clients included the world's two largest shipping alliances, namely 2M Maersk Line and Ocean Alliance (ww.portgdansk.pl).

Table 1 (see Appendix) shows an analysis of container handling in seaports over the past 10 years, based on the statistical data provided by the Port of Gdansk Authority, Port of Gdynia Authority, the Szczecin and Swinoujscie Seaports Authority, and the 2012 Maritime Economy Report (ww.portgdansk.pl).

The data indicate a dynamic growth of container handling in the Port of Gdansk, which has succeeded in maintaining its leading position among Polish seaports. In 2008, Port of Gdynia had a competitive advantage of 425,106 thousand TEU advantage over the Port of Gdansk, and 547,854 thousand TEU over the Szczecin and Swinoujscie Seaports, but in the following year saw a drop of 232,427 thousand TEU in container handling. The reason of the drop was the previously mentioned completion of the Deepwater Container Terminal in Gdansk in 2007, as well as taking over Maersk's vessels from Gdynia, and establishing cooperation with the 2M shipping alliance in 2015 (www.gospodarskamorska.pl). Since 2016 to 2018, the Port of Gdansk has been steadily increasing its cargo volume by 300,000 thousand TEU annually on average. Port of Gdynia has seen an increase of around 100,000 thousand TEU, while the seaports in Szczecin and Swinoujscie have suffered a drop of around 1,000 thousand TEU.

Comparing the cargo handling in the ten largest seaports on the Baltic Sea in 2017 and 2018, the seaports in Gdansk and Gdynia have had strong positions, as shown by Table 2 (see Appendix) (Actia Fortum Raport, 2018).

Port of Gdansk has ranked second for two years in a row in the Baltic container handling rank, just 181,747 thousand TEU behind St Petersburg in 2018 (a 23% year-over-year growth). Por of Gdynia ranked third, taking a narrow lead above Gothenburg and Klaipeda in 2018, and HaminaKotka in 2017. The two Polish seaports have ranked above the ports from Denmark, Finland and Latvia. The total year-over-year growth for the countries listed in the table is 13.92%, indicating a general rise of the container shipping volume.

In the 2018 summary of Europe's largest containerports provided by Shanghai

Maritime University, Port of Gdansk ranked 15 (trailing behind Great Britain by a narrow margin of 1,949-1,995 thousand TEU. The leaders were the ports of Rotterdam, Antwerp and Hamburg (www.obserwatorgospodarczy.pl).

The main competitor of Poland's major seaports on the Baltic Sea are the ports in Russia and Latvia: Ust-Luga, St Petersburg, Primorsk and Klaipėda. Successful operation of the port requires assurance of interaction with other transport modes, thus it is vital to take into consideration the fact that current interaction of network between Klaipėda Seaport and Lithuanian railways is not as effective as it should be. Currently, ports of Klaipėda, Riga and Tallinn have ambitious development plans and they allocate large investments for the improvement of ports' work (figure 2) below shows cargo handling in those ports in 2018 (in million tonnes). The leader was Ust-Luga with 99.0 million tonnes of cargo handled. Port of Gdansk ranked 4th with 49.0 million tonnes of cargo handled, overtaking Klaipėda by 2.4 million tonnes. Port of Gdynia (23.4 million tonnes) ranked 11th, behind the Seaports of Szczecin and Swinoujscie which ranked 8th (28.6 million tonnes) (www.ni.gov.pl). In comparison, in 2015 Port of Gdansk ranked 7th, the Seaports of Szczecin and Swinoujscie ranked 13th, and Port of Gdynia ranked 16th (Klimek, Rolbiecki, 2017).

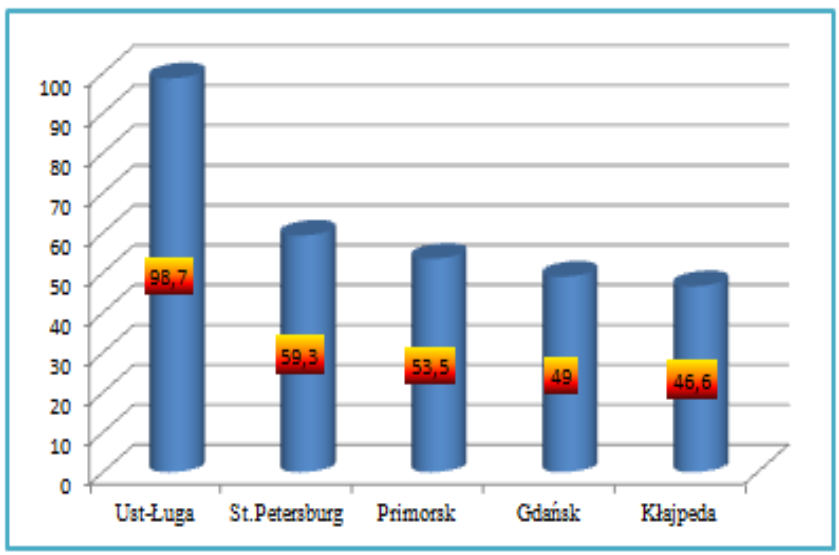

Figure 2. The largest Baltic ports in terms of total cargo handling in 2018 (in million tonnes)

Kłajpeda = Klaipėda

Concerning the growth of handling wheeled cargo transported by Ro-Ro ships, we should highlight the largest and most advanced Baltic ferry terminal in the Szczecin and Swinoujscie Seaports. Located in Swinoujscie, the terminal is a leader in cargo and passenger ferry connections to Scandinavia. It has five specialised handling stations and is capable of handling intermodal transport units (it is the only terminal in Poland to process rail cargo services to and from Sweden). The ferry terminal has seen a steady growth in turnover - in 2013, there were 2,939 ferry calls, in 2015 - 3,327, and in 2018 - 3,827 (www.port.szczecin.pl). Table 3 (see Appendix) below provides a statistical summary of wheeled cargo handling in the largest Polish ports between 2008 and 2018 (www.rynekinfrastruktury.pl).

The volumes of wheeled cargo handled by Poland's key ports show significant differences. Achieving a dominant position on the local or European market and acquiring

new clients, leading to a growth of the handling volume, depend on a variety of factors (Zimon, 2016). One of those factors is the seaport infrastructure which requires continuous upgrades and development in order to meet the increasing needs of the shipping industry.

Using the available statistical data, the value of cargo handling was reviewed, taking into consideration various cargo groups, piece-goods, and dry and liquid bulk cargo. The volume of cargo handled was compared over the decade spanning from 2008 to 2018. Provided below are the cargo handling values in seaports, showing a dominance of piece-goods (over 347 million tonnes), followed by dry bulk cargo (over 271 million tonnes) and liquid bulk cargo (over 164 million tonnes). The vast dominance of piece-goods cargo arises mainly from the high volume of such cargo in each of the seaports throughout the analysed period (2008-2018). It is worth noting the progress of 3,000-6,000 thousand tonnes of cargo handled on average annually between 2013 and 2018 (figure 3).

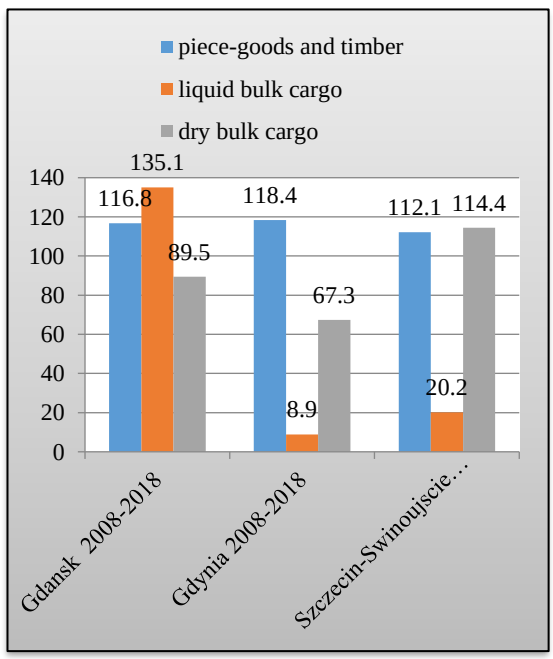

Figure 3. Comparison of the volumes of cargo groups handled over the past decade in Poland's key seaports (in million tonnes)

The Polish seaports in question have seen consistent growth, with the volume of cargo handled according to cargo groups surpassing 101 million tonnes in 2018. The leader is the Port of Gdansk with around 49 million tonnes, followed by the Szczecin and Swinoujscie Seaports with around 28 million tonnes, and Port of Gdynia with around 24 million tonnes.

4. Result

4.1 Container handling in thousand TEU between 2008 and 2018

In 2008, the average cargo handling value in the Port of Gdansk, the Port of Gdynia and the Szczecin and Swinoujscie Seaports amounted to nearly 286.5 million TEU. In 2009, the value dropped to around 224 million TEU, but then saw continuous growth until 2014

when it reached 713.2 million TEU. A higher average container handling value was not reached until 2017 when it amounted to nearly 795 million TEU. In the period in question, the highest average container handling volume in Polish key seaports was achieved in 2018, amounting to 944.8 million TEU) (table 4 and 5 see Appendix).

Using the Kruskal-Wallis test by rank, the following statistically significant ($p<0.001$) differences were shown in the container handling values (in thousand TEU) between the seaports in Gdansk, Gdynia and Szczecin-Swinoujscie. The highest average (annual) value among the analysed ports was found for the Port of Gdansk, with 987,484.45 (± 547,011.66; SD) thousand TEU. The lowest annual average container handling values between 2008 and 2018 was found for the Port of Gdynia, with over 650 million TEU (70,357.36 ± 16,234.09). In the Szczecin and Swinoujscie Seaports, the average annual volume of cargo handled over the analysed decade was over 700 million (653,403.82 ± 133,715.05) TEU (figure 4), (table 6 see Appendix).

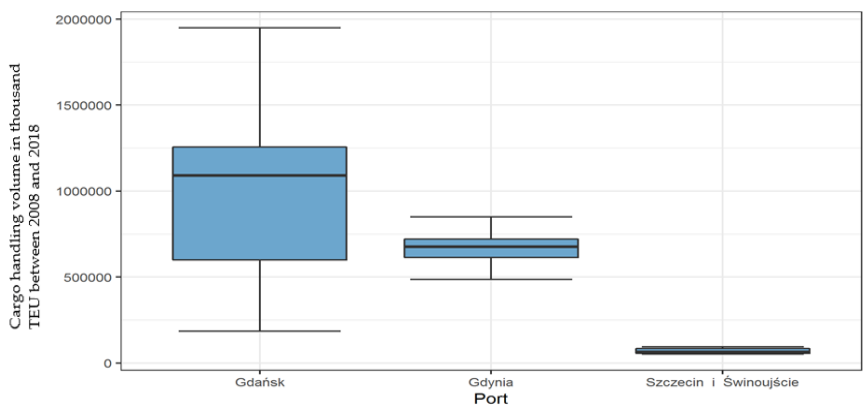

Figure 4. Comparison of container handling volumes in thousand TEU between 2008 and 2018

In order to determine which pair of seaport complexes the significant difference in the annual cargo handling volume applies to, a post-hoc analysis of the Kruskal-Wallis test was performed using Dunn's multiple comparison test with Bonferroni correction (www.rynekinfrastruktury.pl).

No statistically significant differences were found between the values for the Port of Gdansk and the Port of Gdynia (table 7 see Appendix).

It was shown that the handling volume in Gdansk was significantly higher than in the Szczecin and Swinoujscie Seaports ($p<0.001$; Dunn's test with Bonferroni correction). As previously stated, for the port on the Gulf of Gdansk, it was just shy of 987.5 million TEU, while for the ports in the West Pomeranian Voivodeship, the total volume of cargo handled was around 70.4 million TEU (table 8 see Appendix).

Using Dunn's test with Bonferroni correction, it was shown that the Port of Gdynia handled a significantly higher volume of cargo than the Szczecin and Swinoujscie complex (Figure 5 and 6), (table 9 see Appendix).

A strong correlation (Spearman's coefficient = 0.95) was found between the variables related to the year and the sum of cargo handling operations in the analysed Polish seaports for the given year. This showed that the value of the cargo handled increased with time (figure 7), (table 10 see Appendix).

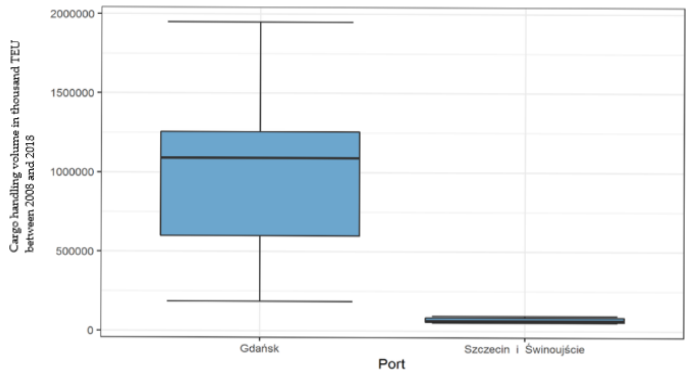

Figure 5. Comparison of the distribution of cargo handling values for the Port of Gdansk and the Szczecin and Swinoujscie Seaports

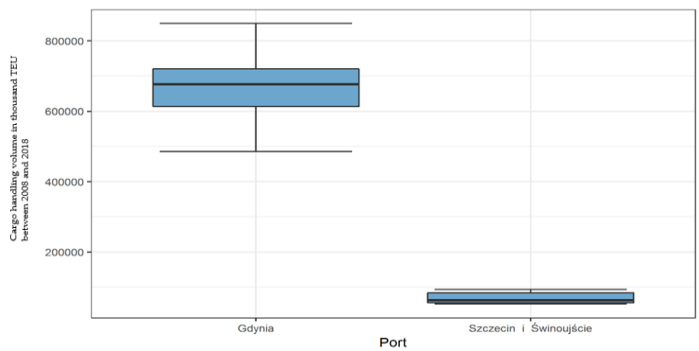

Figure 6. Comparison of the distribution of cargo handling values for the Port of Gdynia and the Szczecin and Swinoujscie Seaports

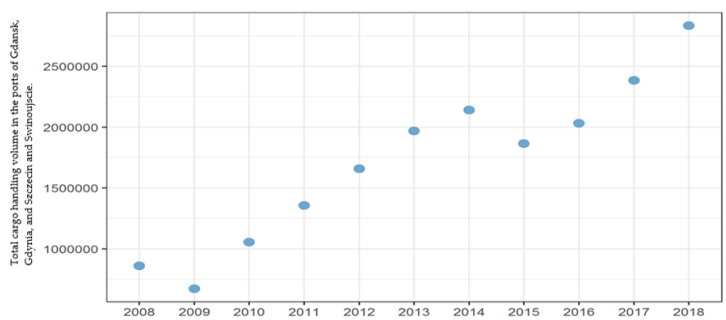

Figure 7. Diagram illustrating the correlation between the variables related to the sum of cargo handling operations and the year

4.1.1 Cargo volumes in Poland's largest seaports (2008-2018), with emphasis on the dominant cargo group in each year (in thousand tonnes)

The performed Kruskal-Wallis test by rank showed statistically significant ($p<0.001$) differences between the cargo volumes of specific types of cargo between 2008 and 2018. The highest average and median values were observed for piece-goods and timber, reaching 31,576.91 (± 9,960.75; average) and 31,070.9 (median) (table 11 see Appendix).

On the basis of Spearman's coefficient and its statistical significance (Dunn, 1959), a strong positive correlation was found between the year and the handling of liquid bulk cargo (Spearman's coefficient = 0.88; $p<0.001$) and dry bulk cargo (Spearman's coefficient = 0.8; $p<0.01$). A very strong positive correlation was found between the year and the handling of piece-goods and timber (Spearman's coefficient = 0.99; $p<0.001$). This means again that the value of the cargo handled increased with time (figures 8, 9 and 10), (table 12 see Appendix).

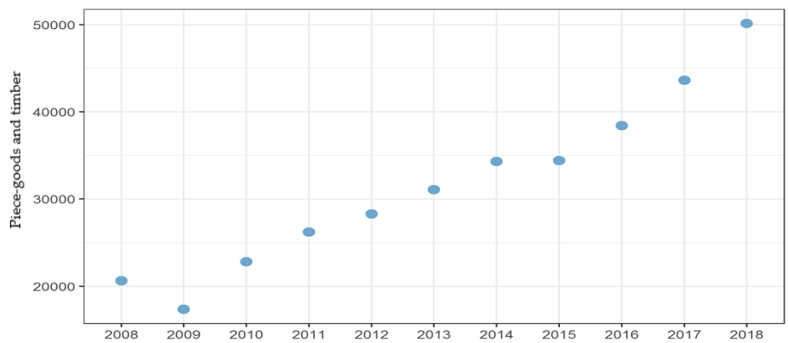

Figure 8. Diagram illustrating the correlation between the variables related to the value of cargo handling (for piece-goods and timber), and the year

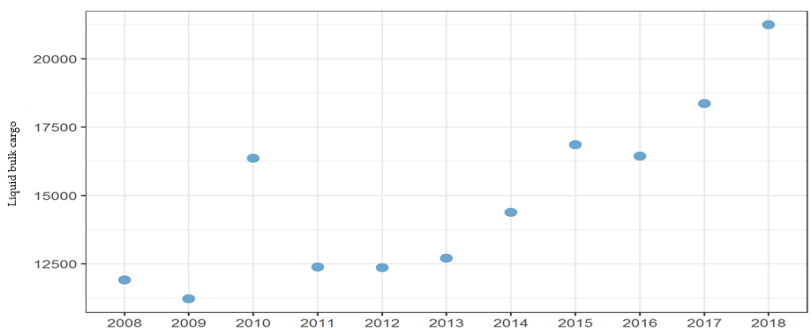

Figure 9. Diagram illustrating the correlation between the variables related to the value of cargo handling (for liquid bulk cargo), and the year

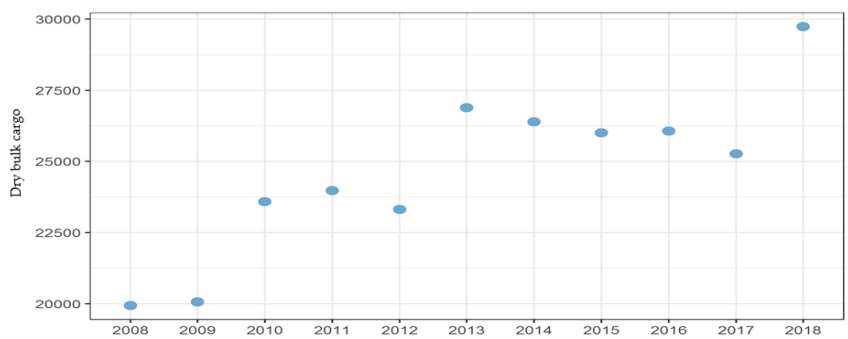

Figure 10. Diagram illustrating the correlation between the variables related to the value of cargo handling (for dry bulk cargo), and the year

4.1.2. Summary of the handling volumes of cargo groups in Poland's key seaports over the past 10 years (in thousand tonnes)

The performed statistical tests indicated statistically significant ($p<0.001$) differences between the cargo volumes in the analysed seaports over the past 10 years. The highest average and median values were found for the Port of Gdansk, amounting to 31,037.69 (± 9,323.79; average) and 30,259.3 (median) (tables 13 and 14 see Appendix).

A very strong positive correlation (Spearman's coefficient >0.9; $p<0.001$) was found between the results for all analysed seaports and the year. This means that the cargo handling in the ports of Gdansk, Gdynia, Szczecin and Swinoujscie grew with each subsequent year.

In 2008, the main type of cargo handled was liquid fuel, with a volume of 10,353.1 thousand tonnes amounting to 58.2% of annual handling volume, followed by dry bulk cargo (24.5%) and piece-goods (17.2%). In 2010, a visible year-over-year growth was observed in the handling volume of piece-goods (by 43.6%) and liquid fuels (by 34.1%), while the volume of grain handled dropped by 23.%. The upwards tendency in 2013 applied mainly to piece-goods, the volume of which was 1,625.9 thousand tonnes higher year over year, and coal, which grew by 2,665.5 thousand tonnes (total year-over-year growth of 12%). In subsequent years, cargo handling volumes saw a steady growth. Highlights included a 6-fold growth of the volume of coal handled over the past decade, and the dominant position of liquid fuels between 2008 and 2016 (in 2016, piece-goods took and timber overtook liquid fuels with a 33% growth by 2018). In percentage terms, the year 2018 looked as follows: piece-goods and timber - 44.5%; liquid fuels - 31.6%; dry bulk cargo - 23.8%.

Analysis of the growth of cargo handling volume between 2008 and 2018 shows that the cargo with the highest growth rate was liquid bulk cargo (135,085.8 thousand tonnes), followed by piece-goods and timber (116,848.5 thousand tonnes) and dry bulk goods (89,480.3 thousand tonnes, of which: I - coal: 40,445.3 thousand tonnes; II - other bulk cargo: 37,764.6 thousand tonnes; III - grain: 11,267.4 thousand tonnes). Summing up, the handling volumes of different cargo groups in the Port of Gdansk between 2008 and 2018 amounted to over 341 million tonnes (figures 11 and 12).

In 2008, the dominant cargo group handled was piece-goods (62.4%), followed by dry bulk cargo (32.9%) and liquid bulk cargo (5.2%). The year 2009 saw a drop in the handling volume by 14.3% compared to the preceding year, caused mainly by the drop of the handling volume of piece-goods and timber by around 3,000 thousand tonnes. In 2011, a visible drop in the volume of liquid fuel handled occurred as compared to 2008 - from 804 thousand tonnes to 591 thousand tonnes, and in 2013, it dropped even further to just below 62 thousand tonnes (in 2016, the liquid fuel volume grew rapidly by 95.3%). After a record volume of 2,726 thousand tonnes in 2011, the dry bulk cargo (i.e. aggregate, sulphur, metal ore) dropped to just 1,094 thousand tonnes in 2017. The highest annual growth trend was observed for piece-goods. In 2018, the share of different types of cargo was as follows: piece-goods and timber - 63%; total dry bulk cargo - 29.5%; liquid bulk cargo - 7.5%.

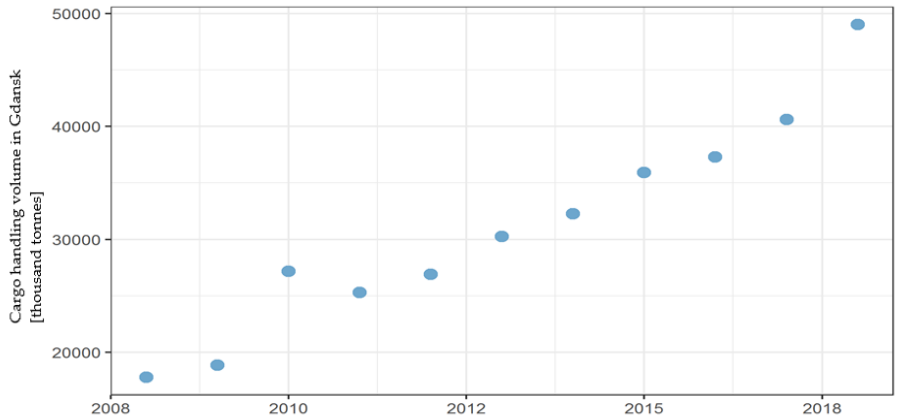

Figure 11. Diagram illustrating the correlation between the variables related to the sum of cargo handling operations in the Port of Gdansk and the year

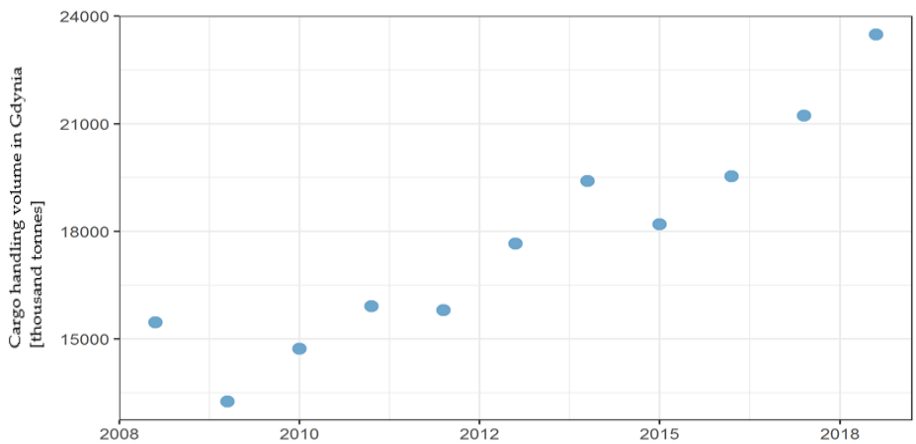

Figure 11. Diagram illustrating the correlation between the variables related to the sum of cargo handling operations in the Port of Gdynia and the year

The year 2009 saw a downwards trend in the volume of dry bulk cargo (mainly coal) by around 20% year over year, but in 2010, there was a rebound by approx. 3,000 tonnes. Between 2008 and 2015, dry bulk cargo handled maintained its leading position among other cargo groups. The trend shifted towards piece-goods, the volume of which grew slightly in 2016 by around 1,000 tonnes. In 2018, the share of different types of cargo was as follows: piece-goods and timber - 47.2%; total dry bulk cargo - 38.9%; liquid bulk cargo - 13.9%.

Summing up the handling volumes of cargo groups over the past decade, the cargo type with the largest share was dry bulk share (114,383.5 thousand tonnes, of which: I - other bulk cargo: 50,760.7 tonnes; II - coal: 47,418.7 thousand tonnes; III - grain: 16,204.1 thousand tonnes), followed by piece-goods and timber (112,038.5 thousand tonnes) and liquid cargo (20,231.8 thousand tonnes). Over the analysed decade, the Szczecin and Swinoujscie Seaports handled a total of over 246 million tonnes of various types of cargo. The cargo handling volumes in seaports show a dominance of piece-goods (over 347 million tonnes), followed by dry

bulk cargo (over 271 million tonnes) and liquid bulk cargo (over 164 million tonnes). The vast dominance of piece-goods cargo arises mainly from the high volume of such cargo in each of the seaports throughout the analysedperiod (2008-2018). It is worth noting the progress of 3,000-6,000 thousand tonnes of cargo handled on average annually between 2013 and 2018 (figures 12 and 13).

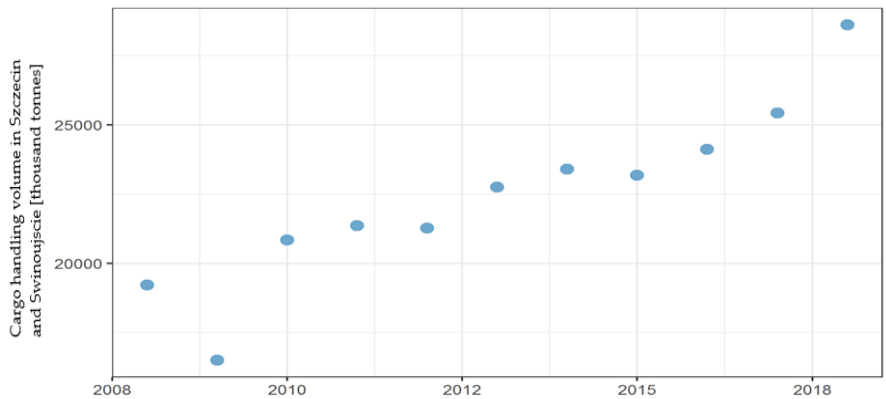

Figure 12. Diagram illustrating the correlation between the variables related to the sum of cargo handling operations in the Szczecin and Swinoujscie Seaports, and the year

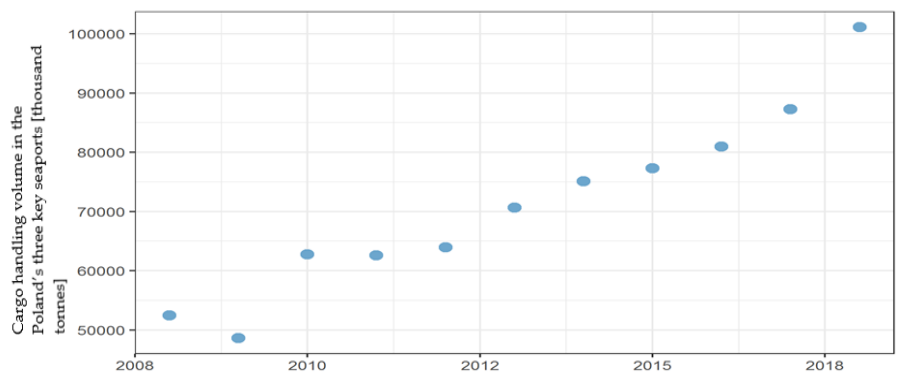

Figure 13. Diagram illustrating the correlation between the variables related to the sum of cargo handling operations in the three seaports and the year

The comparative analysis of cargo handling in the analysed decade indicated a significant upwards trend in all seaports in question. Furthermore, the seaports were also analysed in terms of market competitiveness factors, which highlighted their importance as key junctions linking maritime and land transport and uncovered their weaknesses. Polish seaports have evolved through the years from their basic functions to more complex operations as logistic platforms providing a variety of transport, distribution and logistics services. The seaports integrate the maritime and land sections of supply chains, not only domestic but also for the region of Central and Eastern Europe, improving the flow of logistic networks in the supply chains. Poland's first logistic hub (DCT in Gdansk) allowed the Port of Gdansk to compete on Asian markets. As links in the intermodal logistic chain, Polish seaports are focusing on growing the volume of piece-goods in containers. The cooperation of logistic centres with handling terminals creates value

added throughout the system of transport nodes (in terms of time and cost) (Haezendonck et al. 2006). The role that Poland's key seaports play in the supply chains is as complex logistic nodes (particularly the Port of Gdansk) with more or less developed infrastructure. The weaknesses of Polish seaports include remotelocations and insufficient accessibility.

The largest Polish seaports are important, structurally and systemically complex links in the supply chains of global trade markets. They are transport nodes providing multidimensional cargo handling services, as well as maritime and land logistics services.

4.1.3. Comparison of Polish seaports and other European seaports in terms of cargo handling volume

In 2017, the cargo handling volumes in Polish seaports were trailing behind other European seaports in the summary, which had higher average and median values (figure 14), (table 15 see Appendix).

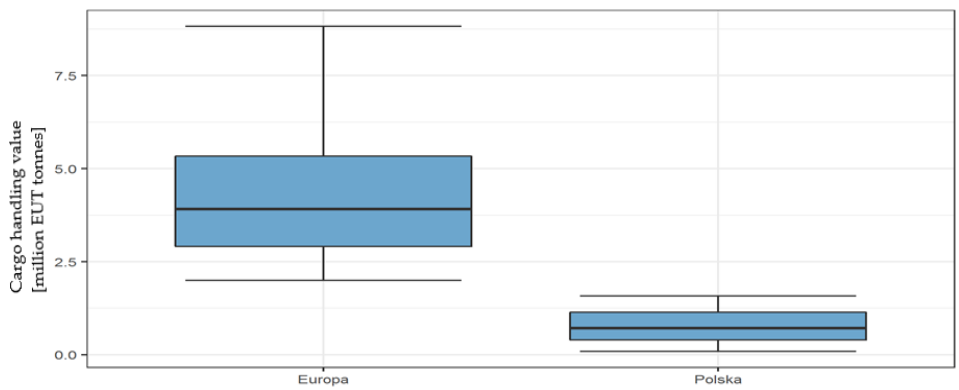

Figure 14. Comparison of the distribution of cargo handling value in Polish and European seaports in 2017

Provided below are descriptive statistical data on the cargo handling volumes in European seaports in 2017. The seaport with the highest cargo handling volume was Antwerp with 10.45 million EUT tonnes, while the lowest were the Szczecin and Swinoujscie Seaports with 0.09 million EUT tonnes (figure 15), (tables 16, 17 and 18 see Appendix).

The following tables provide the cargo handling volumes in European seaports in 2018. Similar to 2017, the seaport with the highestcargo handling volume was Antwerp with 11,10 million EUT tonnes, while the lowest were the Szczecin and Swinoujscie Seaports with 0.08 million EUT tonnes (table 19, 20 and 21 see Appendix).

The geographical location of Poland's key seaports can be analysed twofold - in terms of competitiveness on the Baltic Sea, or in a broader perspective of the North Sea and the entire region of Central and Easter Europe. The remoteness refers mainly to the location of the Baltic Sea relative to the well-developed industrial centres in the south which have better access to the seaports on the North Sea (Rotterdam, Antwerp, Hamburg, Bremerhaven), and for which the costs related to port services and additional transit play an important role. One of the natural limitations of Polish seaports are the shipping routes through the Danish straits (with max. depth of 15 metres). At the moment, Polish seaports have access to those routes, but the global development of trade markets and the parameters of large ocean-going vessels might prove to be significant obstacles. In terms of competitiveness in the Baltic perspective, Polish seaports count

among the most rapidly growing and evolving. In the statistical data of cargo handling in 2018, the Port of Gdansk ranked second (with 1,948,974 thousand TEU) after the Russian seaport of St Petersburg, with the Port of Gdynia ranking third (803,871 thousand TEU), ahead of the seaports in Sweden, Finland, Denmark and Lithuania. In terms of the total cargo handling volume, the Port of Gdansk ranked fourth in 2018 behind the Russian ports, ahead of the Lithuanian complex in Klaipėda by 2.41 million tonnes (Rees, 2018). The second perspective of competitiveness against other seaports on the North Sea is less favourable, due mainly to the remote location of the Polish seaports which affects the accessibility to economic and industrial centres (thus affecting transit operations), and the superior infrastructure of the Western European seaports arising directly from the higher demand for port services. In terms of the cargo handling volume statistics, the Port of Gdansk ranked 15th among the European seaports in 2018, with the leading position taken by the British seaports.

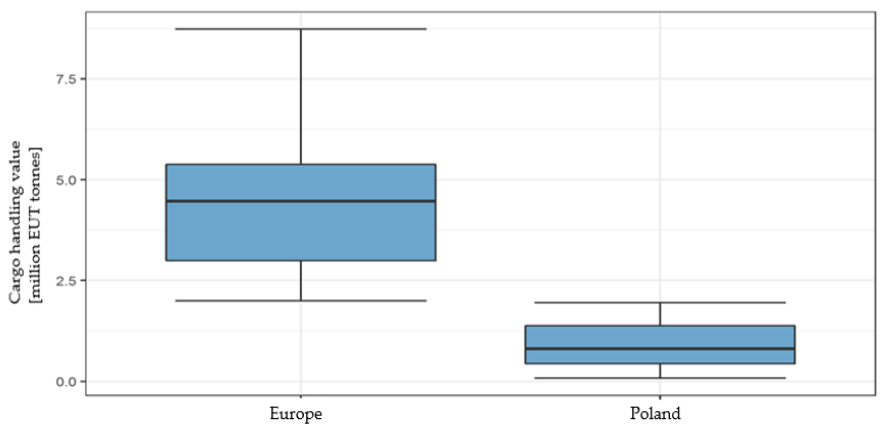

Figure 15. Comparison of the distribution of cargo handling value in Polish and European seaports in 2018

Location is a major factor in terms of accessibility of the seaport from the sea, from the land and for inland shipping. The accessibility from the sea depends on the infrastructure and technical parameters of the given sea area which determine the acceptable size and draught of the vessels. Seaport development, mainly in terms of deepening the terminals, increase the seaport's cargo handling capacity and is a necessary strategic move for developing and expanding container terminals. Poland's deepest seaport is the Port of Gdansk (Deepwater Container Termina) which has the depth of 15 m (17 m at the port entrance), which processes oceanic routes and the largest container ships on the Baltic Sea. The other Polish seaports are shallower (Port of Gdynia -13 m; Szczecin and Swinoujscie Seaports: 9.15 m in Szczecin, 13.5 m in Swinoujscie), but the development strategy of those ports involves deepening. The Program for the development of Polish seaports to 2020 (with a perspective to 2030) includes, among others, plans for developing the piers and terminals of the largest seaports in Poland. In particular, the schedule of planned works includes deepening and widening the Szczecin - Swinoujscie shipping channel on the Oder river, and deepening the areas for new developments (Central Port in Gdansk, Outer Port in Gdynia, and, partially, the Deepwater Container Terminal in Swinoujscie). For a potential shipowner

choosing the seaport for its services, the technical parameters and the waiting time in the port. With the exception of Szczecin, all of the discussed Polish seaports are located directly on the Baltic Sea. Due to its location, the time criterion is unfavourable for Szczecin. The Western Pomeranian complex profits from the proximity with the industrial centres of the southwestern Poland (Wroclaw, Poznan, Upper Silesia). The seaports in Szczecin and Swinoujscie are located close to the German seaports and are used as transit nodes for trade from the Czech Republic and Slovakia. Another important infrastructural element of the seaport in terms of accessibility from the sea is harmonising the growing demand for services with the development of specialised terminals with the equipment suitable for handling specific cargo. All the components of the infrastructure and the suprastructure have a direct impact on the quality of service in the form of the waiting time for handling operations, security, and operational costs. The seaports in Gdansk, Gdynia, and in Szczecin and Swinoujscie have specialised equipment for handling various types of cargo (Rees, 2018).

The accessibility of the seaport from land is determined by the road and railway network, and the accessibility for inland shipping. The Polish seaports which generate the most added value serve as the key transport junctions in the Trans-European Transport Network (TEN-T) (the route (the Baltic-Adriatic Corridor), connected to the key Polish roads, in particular Motorway A1 and Expressway S7 for Gdansk and Gdynia, and Expressway S3 and Motorway A6 for Szczecin and Swinoujscie.

5. Discussion

According to the 2018 report of the Polish Supreme Audit Office, the road infrastructure has significantly improved in the recent years, but the 2014-2023 National Road Construction Programme does not specify building new high-quality roads (Article 17 sec. 3 of the Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network). The worst situation is found on the "last mile" sections, leading to the gate of the seaport (access roads with reduced load-bearing capacity). This applies to the Port of Gdynia, where the road leading to the seaport is a district road (TrasaKwiatkowskiego). A positive sign for the future is the planned "Red Road", included on the list of the infrastructural projects of the Baltic-Adriatic Corridor, which will solve the current accessibility issues, but the project will span over a long period of time and will require significant expenditures. The plan for the road has been legally approved in 2019 and will take around 7 years to complete. Railway connections look better, because aside from the national railroads leading to seaports (E59/C-E 59 to the Szczecin and Swinoujscie Seaports; E65, C-E 65 to the Port of Gdansk and the Port of Gdynia), the 2019-2020 development strategy specifies upgrading the railway stations which handle traffic to the key seaports. The plans provided in the seaport access improvement strategies to 2027 also specify upgrading the road and railway infrastructure to enable the flow of intermodal traffic at the terminal containers. The accessibility of seaports for inland shipping requires thorough modernisation of the river shipping channels (as specified in the 2016-2020 development plan with the perspective to 2030), which will include the Vistula-Gdansk, the Oder-Silesian Channel, and the Oder-Vistula connections (Lees, 2012). Aside from theWest Pomeranian seaport complex, the other two key Polish seaports have no access to inland shipping. The Szczecin and Swinoujscie Seaports is the only port complex with access to inland shipping on the Oder, which provides connection to the transit routes from and to the German seaports. Improving the access infrastructure will increase the flow in the transport operations of the logistic networks and will

improve the competitiveness on the market.

Further development of Polish seaports

The plan for the development of Poland's seaports, provided in the Program for the development of Polish seaports to 2020 (with a perspective to 2030) includes major investments in the transport infrastructure (intermodality), and the distribution and logistics infrastructure to reinforce the Polish seaports' position in the supply chains. The programme's main items include building the Central Port in Gdansk, the Outer Port in Gdynia, and the Deepwater Terminal in Swinoujscie - by land reclamation. This strategic move of developing the infrastructure "outwards" to the sea is an innovative approach, with the development of the water area physically expands the port and improves accessibility from the sea. Further infrastructural developments are also crucial, such as widening the Szczecin-Swinoujscie shipping channel, building an intermodal logistic terminal, upgrading the rail switches and improving the rail and road traffic flow in Gdynia). The development potential of the seaports depends on the capital expenditures and the available land. The planned investments will lead to a growth of the cargo handling volume in the Polish seaports, improving the handling capacity and throughput, and the transport and logistic processes.

Cargo handling in Polish seaports between 2008 and 2018 shows a steady upwards trend in all analysed ports. This refers in particular to the Port of Gdansk which since 2010 has been the leader in the total volume of cargo handled, with over 49 million tonnes in 2018; in the Port of Gdynia, the volume was 23 million tonnes, while in the Szczecin and Swinoujscie Seaports it was 28 million tonnes.

The growth of trade generates dynamic growth of the volume of container cargo. Based on the research conducted by the Gdynia Maritime University, a significant growth of the volume of container cargo on the Baltic Sea is forecasted in the coming years, reaching 25 million TEU annually by 2030 (www.mgm.gov.pl). This justifies the investments in the container terminals in the Polish seaports, which generate demand for services related to the handling of the container transport units. With its Deepwater Container Terminal, the Port of Gdansk is an unquestionable leader - building the second pier increased turnover twofold. The seaport in Gdansk benefits by becoming, as Poland's only key seaport, a logistic hub capable of processing ocean-going vessels (the remaining seaports are used as transport and supply nodes for feeder connections). With the completion of the first DC, 2010 was a breakthrough year for container cargo handling in the Polish maritime economy. The Gdansk hub took over some of the feeder connections from the port of Hamburg (which was previously known as the "Polish port"). Establishing cooperation with Maersk 2M and Ocean Alliance provided a further boost for developing connections with the Far East. Building the Pomeranian Logistics Centre near the DCT in Gdansk was a carefully planned, strategic move to build the intermodal capacity in the Port of Gdansk. The compatibility of services provided in the distribution and logistics centres, and in container terminals, generates added value in the form of optimising the duration of the cargo handling operations and improving the quality of service in the supply chains (www.port.gdynia.pl). Tailoring the port services to the growing and changing market needs has been a priority for the Polish seaports. The Port of Gdynia and the West Pomeranian seaports also invest in complex systems combining different modes of transport (infrastructure development - building logistics centres in the proximity of the terminals). One of the key elements to be implemented in the near future will be the Port Community System - an information exchange system (digitalisation - to be implemented by the end of 2020) which will facilitate the cooperation between the participants of the maritime and land supply chains.

6. Conclusion

Today's modern seaports are not only the meeting point of maritime transport and land transport, but also logistics and information centers of crucial importance for the land-sea transport chain. A disruption of the information flow in a seaport is associated with a disruption of the organization within the port area, and this leads to a disruption (and in the worst case, an interruption) of the transport chain.

Poland has a 524 km long seacoast with five major ports, four of which - Gdansk, Gdynia, Szczecin and Swinoujscie - are of fundamental importance for the national economy.

Studies have shown that as members of TEN-T, Poland's seaports have a strong position in the complex systems of logistic nodes in the European and global supply chains. Furthermore, between 2008 and 2018, Polish seaports saw a visible growth in the volume of the cargo handled (thanks to the completed and continuing investments in infrastructure development), as shown in this paper. Despite the remote location of Polish seaports, which limits their development potential somewhat, they remain competitive against other European ports, as also demonstrated herein. The logistic hub in Gdansk will improve the competitiveness of the Polish economy on trade markets.

Studies have shown that the accessibility of the seaports from the sea and from land requires improvement due to the lack of access to inland shipping. It should be pointed out that the Polish seaports are versatile, capable of handling various cargo groups and equipped with the specialised infrastructure.Developing the Polish seaports towards intermodality (creating a grid of intermodal connections in maritime and land supply chains using railways) and integrating the cargo handling terminals with the logistics centres generates added value and improves the quality and availability of port services.

Despite the completed investments and the growth of the cargo volume between 2008 and 2018, Polish seaports require continuous development to be able to respond to the growing needs of the trade markets. Otherwise, the competition of the seaports on the North Sea and other Baltic ports may pose a major threat to Polish seaports. Thus, it can be concluded that investments in the nodal infrastructure of maritime transport should be aligned with the investments in the linear infrastructure. The development plans for the coming years will reinforce the position of Polish seaports on the highly competitive market of the Baltic Sea and the North Sea.

The role of seaports in the land-sea transport chains increased along with the achievement of subsequent stages of development, known as seaport generations. In order to remain competitive in the land a transport and logistics chains, seaports should ensure the speed and quality of ship service, translating in to the price of the service, and convenient access to the port from the hinterland, because these basic factors determine the choice not only of a seaport, but also the routes of the entire "chain". The construction of the DCT Gdansk terminal made the port of Gdansk significant Baltic hub and led to the establishment of the Pomeranian Logistics Center.

The development of Polish ports is an integrated task which requares evaluation of possible cargo flows during certain period, possible changes of flows, port investments, influence of other ports on cargo flows, variation of transportation prices, etc. This requires further market research. The connections of the ports with transport and logistics network of neighbouring countries allows to achieve the synergy effect and benefit from cooperation between different stakeholders within international supply chain.

Maritime transport and seaports are key constituents of the global logistics and transport system. Both shipping and seaport activities have historically been affected by a

goods explosion phase, which resulted in the current level of market segmentation based on commodity types. Still, the different market segments in shipping and port activity are to some extent functionally linked and the markets exert a strong sense of a common market sentiment. Maritime transport and seaports will have to respond to an increasing need for cost efficiency, reliability, flexibility, resilience and sustainability while accommodating global commodity flows.

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Appendix:

Table 1. Container handling in thousand TEU in Poland's largest seaports between 2008 and 2018

2008-2018	Gdansk	Gdynia	Szczecin and Swinoujscie	Total
2008	185,661	610,767	62,913	859,341
2009	240,623	378,340	52,809	671,772
2010	511,876	485,255	56,503	1,053,634
2011	685,643	616,441	55,098	1,357,182
2012	928,905	676,349	52,179	1,657,433
2013	1,177,623	729,607	62,307	1,969,537
2014	1,212,054	849,123	78,439	2,139,616
2015	1,091,202	684,796	87,784	1,863,782
2016	1,299,373	642,195	90,869	2,032,437
2017	1,580,505	710,698	93,579	2,384,782
2018	1,948,974	803,871	81,451	2,834,296

Table 2. The ranking of largest Baltic container seaports for 2017 and 2018 (in thousand TEU)

The largest container ports on the Baltic Sea	2017	2018	Change 2018/2017
St. Petersburg	1920 650	January - 2,130,721	10.94%
Gdansk	1,580,508	February - 1,948,974	23.31%
Gdynia	710,698	March - 803,871	13.11%
HaminaKotka	690,326	June - 653,429	-5.35%
Gothenburg	643,000	April -753,000	17.11%
Aarhus	511,424	July - 540,363	5.67%
Klaipėda	472,998	May - 750,000	58.56%
Helsinki	491,000	August - 509,532	3.77%
Riga	445,984	September - 469,342	5.24%
Rauma	277,507	October - 262,667	-5.35%
TOTAL	7,744,095	8,821,899	13.92%

Table 3. Summary of wheeled cargo (S - self-propelled; NS = non-self-propelled) in Poland's largest ports between 2008 and 2018 (in thousand tonnes)

2008-2018	Gdansk			Gdynia			Szczecin and Swinoujscie			Total
	S	NS	total	S	NS	total	S	NS	total	
2008	592.8	8.9	**601.7**	1152.2	739.6	**1,891.8**	2,648.9	571.7	**3,220.6**	5,714.1
2009	322.8	13.2	**336.0**	865.1	483.2	**1,348.3**	2,695.7	430.0	**3,125.07**	4,809.37
2010	346.1	14.5	**360.6**	1041.6	497.7	**1,539.3**	3,474.7	477.9	**3,952.6**	5,852.5
2011	326.6	21.2	**347.8**	991.4	579.7	**1,571.1**	3,822.8	459.3	**4,282.1**	6,201.0
2012	263.4	31.1	**294.5**	1,079.8	455.8	**1,535.6**	3,894.0	508.4	**4,402.4**	6,232.5
2013	118.1	14.9	**133.0**	1,288.1	421.6	**1,709.7**	4,080.9	449.2	**4,530.1**	6,372.8
2014	103.3	13.9	**117.2**	1,499.0	454.5	**1,953.5**	4,517.3	521.0	**5,038.3**	7,109.0
2015	149.2	14.5	**163.7**	1,600.8	442.2	**2,043.0**	5,060.0	492.8	**5,552.8**	7,759.5
2016	169.2	37.2	**206.4**	1,743.8	524.3	**2,268.1**	5,447.7	483.4	**5,931.1**	8,405.6
2017	198.2	88.6	**286.8**	1,759.8	566.6	**2,326.4**	5,873.2	445.8	**6,319.0**	8,932.2
2018	243.2	50.8	**304.0**	1,790.7	714.3	**2,504.3**	5,953.0	468.0	**6,421.0**	9,229.3

Table 4. Comparison of container handling volumes in thousand TEU in specific years (part 1)

Variable	Parameter	2008 (N=3)	2009 (N=3)	2010 (N=3)	2011 (N=3)	2012 (N=3)
Container handling in thousand TEU	N	3	3	3	3	3
	Average (SD)	286,447 (287,496.72)	223,924 (163,406.7)	3,512,11.33 (255,571.75)	452,394 (345,803.86)	552,477.67 (451,298.35)
	Median (IQR)	185,661 (124,287 - 398,214)	240,623 (146,716 - 309,481.5)	485,255 (270,879 - 498,565.5)	616,441 (335,769.5 - 651,042)	676,349 (364,264 - 802,627)
	Range	62,913 - 610,767	52,809 - 378,340	56,503 - 511,876	55,098 - 685,643	52,179 - 928,905

Table 5. Comparison of container handling volumes in thousand TEU in specific years (part 2)

2013 (N=3)	2014 (N=3)	2015 (N=3)	2016 (N=3)	2017 (N=3)	2018 (N=3)
3	3	3	3	3	3
656,512.33 (561,239.31)	713,205.33 (578,900.64)	621,260.67 (504,717.22)	677,479 (605,024.13)	794,927.33 (747,032.91)	944,765.33 (941,700.03)
729,607 (395,957 - 953,615)	849,123 (463,781 - 1,030,588.5)	684796 (386,290 - 887,999)	642,195 (366,532 - 970,784)	710,698 (402,138.5 - 1,145,601.5)	803,871 (442,661 - 1,376,422.5)
62,307 - 1,177,623	78,439 - 1,212,054	87,784 - 1,091,202	90,869 - 1,299,373	93,579 - 1,580,505	81,451 - 1,948,974

Table 6. Comparison of container handling volumes in thousand TEU between 2008 and 2018 in specific seaports

Variable	Parameter	Gdansk (N=11)	Gdynia (N=11)	Szczecin and Swinoujscie (N=11)	test	P -value
Container handling in thousand TEU between 2008 and 2018	N	11	11	11	Kruskal-Wallis test by rank	**<0.001**
	Average (SD)	987,494.45 (547,011.66)	653,403.82 (133,713.05)	70,357.36 (16,234.09)		
	Median (IQR)	1,091,202 (598,759.5 - 1,255,713.5)	676,349 (613,604 - 720,152.5)	62,913 (55,800.5 - 84,617.5)		
	Range	185,661 - 1,948,974	378,340 - 849,123	52,179 – 93,579		

Table 7. Comparison for Port of Gdansk and Port of Gdynia

Variable	Parameter	Gdansk (N=11)	Gdynia (N=11)	test	p-value
Container handling in thousand TEU	N	11	11	Dunn's multiple comparison test with Bonferroni correction	0.094
	Average (SD)	987,494.45 (547,011.66)	653,403.82 (133,713.05)		
	Median (IQR)	1,091,202 (598,759.5 - 1,255,713.5)	676,349 (613,604 - 720,152.5)		
	Range	185,661 - 1,948,974	378,340 - 849,123		

Table 8. Comparison for the Port of Gdansk and the Szczecin and Swinoujscie Seaports

Variable	Parameter	Gdansk (N=11)	Szczecin and Swinoujscie (N=11)	test	p-value
Container handling in thousand TEU	N	11	11	Dunn's multiple comparison test with Bonferroni correction	**<0.001**
	Average (SD)	987,494.45 (547,011.66)	70,357.36 (16,234.09)		
	Median (IQR)	1,091,202 (598,759.5 - 1,255,713.5)	62,913 (55,800.5 - 84,617.5)		
	Range	185,661 - 1,948,974	52,179 - 93,579		

Table 9. Comparison for the Port of Gdynia and the Szczecin and Swinoujscie Seaports

Variable	Parameter	Gdynia (N=11)	Szczecin and Swinoujscie (N=11)	test	p-value
Container handling in thousand TEU	N	11	11	Dunn's multiple comparison test with Bonferroni correction	**<0.001**
	Average (SD)	653,403.82 (133,713.05)	70,357.36 (16,234.09)		
	Median (IQR)	676,349 (613,604 - 720,152.5)	62,913 (55,800.5 - 84,617.5)		
	Range	378,340 - 849,123	52,179 - 93,579		

Table 10. Correlation between the year and the sum of cargo handling operations

Spearman's coefficient	p-value
0.95	**<0.001**

Table 11. Comparison for specific cargo groups

Variable	Parameter	Piece-goods and timber (N=11)	Liquid bulk cargo (N=11)	Dry bulk cargo (N=11)	test	p-value
Cargo volumes in Poland's largest seaports between 2008 and 2018 (in thousand tonnes)	N	11	11	11	Kruskal-Wallis test by rank	**<0.001**
	Average (SD)	31,576.91 (9,960.75)	14,928.6 (3,176.08)	24,655.11 (2,913.86)		
	Median (IQR)	31,070.9 (24,518.4 - 36,429.35)	14,382.4 (12,368.7 - 16,643.05)	25,263 (23,445.85 - 26,228.4)		
	Range	17,342.3 - 50,153.8	11,220.7 - 21,244	19,932.7 - 29,738.7		

Table 12. Correlation with the year

	Spearman's coefficient	p-value
Piece-goods and timber	0.99	**<0.001**
Liquid bulk cargo	0.88	**<0.001**
Dry bulk cargo	0.8	**0.005**

Table 13. Comparison of the handling volumes of cargo groups in Polish seaports

Variable	Parameter	Gdansk (N=11)	Gdynia (N=11)	Szczecin and Swinoujscie (N=11)	test	p-value
Value	N	11	11	11	Kruskal-Wallis test by rank	**0.0003**
	Average (SD)	31,037.69 (9,323.79)	17,698.55 (3,045.63)	22,423.07 (3,196.73)		
	Median (IQR)	30,259.3 (26,101.75 - 36,601.25)	17,659 (15,638.5 - 19,469)	22,750 (21,054.75 - 23,757.2)		
	Range	17,780.9 - 49,032.3	13,257 - 23,490	16,497.7 - 28,614.2		

Table 14. Correlation with the year

	Spearman's coefficient	p-value	Pearson's correlation coefficient	p-value
Gdansk	0.97	**<0.001**	0.97	**<0.001**
Gdynia	0.95	**<0.001**	0.94	**<0.001**
Szczecin and Swinoujscie	0.97	**<0.001**	0.93	**<0.001**
Total	0.98	**<0.001**	0.97	**<0.001**

Table 15. Comparison of Polish seaports and other European seaports in terms of cargo handling volume in 2017

Variable	Parameter	Europe (N=14)	Poland (N=3)
Cargo handling [million EUT tonnes]	N	14	3
	Average (SD)	5,12 (3,47)	0.8 (0.75)
	Median (IQR)	3,92 (2,91 - 5,34)	0,71 (0,4 - 1,15)
	Range	2 - 13,73	0,09 - 1,58

Table 16. Comparison of Polish seaports and other European seaports in terms of cargo handling volume in 2017 (part 1)

Port	Algeciras (N=1)	Antwerp (N=1)	Barcelona (N=1)	Bremerhaven (N=1)	Felixstowe (N=1)	Gdansk (N=1)	Gdynia (N=1)	Genoa (N=1)	GioiaTauro (N=1)
Cargo handling [million EUT tonnes]	4.38	10.45	2.97	5.51	3.77	1.58	0.71	2.62	2.45

Table 17. Comparison of Polish seaports and other European seaports in terms of cargo handling volume in 2017 (part 2)

Port	Hamburg (N=1)	Le Havre (N=1)	Marsaxlok k (N=1)	Piraeus (N=1)	Rotterdam (N=1)	Southampt on (N=1)	Szczecin and Swinoujsci e (N=11)	Valencia (N=1)
Cargo handling [million EUT tonnes]	8.82	2.88	3.15	4.06	13.73	2	0.09	4.83

Table 18. Comparison of Polish and European seaports in 2018

Variable	Parameter	Europe (N=14)	Poland (N=3)
Cargo handling	N	14	3
	Average (SD)	5.38 (3.64)	0.94 (0.94)
	Median (IQR)	4.47 (2.99 - 5.38)	0.8 (0.44 - 1.38)
	Range	2 - 14.51	0.08 - 1.95

Table 19. Comparison of Polish seaports and other European seaports in terms of cargo handling volume in 2018 (part 1)

Port	Algeciras (N=1)	Antwerp (N=1)	Barcelona (N=1)	Bremerhaven(N=1)	Felixstowe (N=1)	Gdansk (N=1)	Gdynia (N=1)	Genoa (N=1)	GioiaTauro (N=1)
Cargo handling [million EUT tonnes]	4.77	11.10	3.42	5.47	**4.16**	1.95	0.8	2.61	2.3

Table 20. Comparison of Polish seaports and other European seaports in terms of cargo handling volume in 2018 (part 2)

Port	Hamburg (N=1)	Le Havre (N=1)	Marsaxlokk (N=1)	Piraeus (N=1)	Rotterdam (N=1)	Southampton (N=1)	Szczecin and Swinoujscie (N=11)	Valencia (N=1)
Cargo handling [million EUT tonnes]	8.73	**2.88**	3.31	4.91	14.51	2	0.08	5.1

Table 21. Comparison of cargo handling volumes in 2017 and 2018

Variable	Parameter	2017 (N=17)	2018 (N=17)
Cargo handling	N	17	17
	Average (SD)	4.35 (3.57)	4.59 (3.73)
	Median (IQR)	3.15 (2.45 - 4.83)	3.42 (2.3 - 5.1)
	Range	0.09 - 13.73	0.08 - 14.51