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Article

The Impact of Improving the Quality of the Port's Infrastructure on the Shippers' Decisions

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Abstract: Important attributes of a transportation chain are the costs of their operation, the security of supply they provide, and reducing carbon emissions throughout the chain. When making managerial decisions about the chain configuration, shippers consider the optimal choice of means of transport, carriers, or ports. Seaports, as transport nodes, determine the functioning of supply chains they serve. A constant process observed in the world shipping is the consistent increase in the average size of ships. Adapting the port and port access infrastructure to the changes observed in the world shipping is a prerequisite for maintaining the competitive position of the port, and consequently of the entire transport chain. Adequate hydrological conditions ensuring safe access to ports for increasingly larger ships are necessary for the stable functioning and development of a port and the entire region. For shippers, the certainty that the handling of larger vessels is assured regardless of any fluctuating hydro-meteorological conditions and temporary vessel entry permits is a guarantee of security of supply. This study aims to demonstrate the impact of fairway deepening on port-oriented supply chain costs and security of supply, as well as verification of the importance of these factors for cargo shippers' decision-making. The article used the case study method based on the port of Szczecin, for which the investment of deepening the fairway to 12.5 m is being implemented. The article estimates the transport costs of five transport chains served by the port of Szczecin. Our research showed that a 2.5 m increase in the permissible draught of ships results in a decrease of up to 25% in transport costs resulting mainly from the reduction in specific fuel consumption throughout the chain. The analysis of the results showed that a secondary benefit of deepening the fairway can change the structure of the port's foreland. This conclusion was validated by means of in-depth interviews held with selected shippers cooperating with the port of Szczecin. An additional outcome of the interviews was identification of the remaining conditions that should be met to take full advantage of improved port accessibility. The research is the first step to broader studies assessing whether improving quality of port infrastructure can contribute to a reduction in emissions from ships in a port and thus facilitate the transition to zero-emission ports.

Keywords: seaport; port infrastructure; decision making; transport costs; security of supply; ship size

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1. Introduction

Over the past 40 years, significant changes in international marine trade have taken place. In that period, the maritime transport volume has risen from 3.7 bn tonnes in 1980 to 10.6 bn tonnes in 2020. In the geographical aspect, in accordance with the general trends in the world trade, the largest share in this exchange is now held by internal and international trade conducted by Asian countries. As for trends in the world cargo vessel fleet, the most significant feature is the tendency to increase the capacity of newly built vessels compared with the ones that are now being decommissioned or the ones that were built in previous years. Currently, the mean capacity in the newest (0–4 years) world cargo vessel fleet exceeds 43,000 DWT [1]. The said changes are also reflected in seaport development strategies that enhance the importance of deepening the seaport fairway to enable access for larger vessels.

Port authorities must take decisions that adapt the port's infrastructure not only to increasingly larger ships, but also, i.a., to climate change [2] and new solutions related to ship propulsion [3] without forgetting the need to maintain an adequate level of competitiveness. It is believed that ports will play a key role in shaping the current policy landscape of shipping towards its low-carbon transformation [4]. New ships calling at ports will require technologies and tools such as cold ironing infrastructure or LNG refuelling infrastructure [5]. Port authorities can promote energy management by coordinating energy use and the uptake of renewables [6].

The research studies completed so far have examined investments in nautical access and port infrastructures mainly in the aspect of their impact on the competitiveness of seaports as links of sea-land supply chains. The literature on the subject far less frequently confronts the research results with cargo shippers' opinions. This is the main reason why the authors of this study decided to undertake the research study and present its results.

The importance of cargo shippers' opinions is underlined by the complex nature of factors that they take into account while making their choices. In addition to the typical economic factors, the literature on the subject indicates issues connected, i.a., with loyalty to the ports they have been cooperating with so far, and the time needed to change their decision [7]. There are various entities responsible for the quality of port factors that are important for cargo shippers. In addition to the factors controlled by the public sphere of seaports, some factors fall within their private sphere.

The seaport in Szczecin, the object of the research study described in this study, is one of the major seaports in Poland and is classified as a secondary port. Over the past decade, the major Polish seaports have experienced a distinct rise in the share of cargoes coming from the extra-European foreland. An exception is the port in Szczecin (the parameters of its sea access infrastructure and of the port infrastructure are the worst among the major Polish seaports), as it is capable of handling fully loaded vessels of a capacity of maximum 20 k DWT. This situation prevents the port in Szczecin from effective procurement of cargoes coming from the extra-European foreland. In this context, the currently implemented project consisting in deepening the fairway to the port in Szczecin up to 12.5 m is in line with the challenges connected with improving the port's competitiveness. Providing a possibility of handling one-off consignments of 40–50 k tonnes will enable the port to meet the logistic minima for many cargoes transported to/from the distant foreland.

For many cargo shippers located in the hinterland of the Szczecin port, the new depths to be provided in the port and its fairway constitute a key factor that makes it possible to include the Szczecin port as a link of sea-land supply chains, or to increase cargo volumes handled so far in Szczecin. However, most of the shippers need some other conditions to be met in order to be able to make a decision in that respect.

The research study conducted by the authors of this study supplied evidence regarding the dynamic change in cargo transport costs and shippers' behaviours in a situation when the port parameters have actually changed. For the researchers, the deepening of the fairway and the adjustment of the infrastructure in the port of Szczecin to enable handling of larger seagoing vessels constitutes an exceptional occasion to examine decisions made by shippers since the seaport access parameters are being improved here and now. Thus, the interviews we held with the shippers pertained to an actual rather than a hypothetical situation, and regarded the dilemmas that the shipper will be facing shortly. For that reason, the responses obtained during the interviews constitute a valuable source of knowledge about shippers' propensity to modify supply chain configurations, being reliable evidence regarding the port choice issue which has not yet been fully examined.

A hypothesis was formulated as follows: Investments in port access infrastructures have an impact on decreasing the total cost of port-oriented supply chains and improving the supply security, as a result of which they contribute to increasing the transshipment volumes in the port and to changing the port's foreland structure.

Overall, this study adds more evidence and extends the literature in the area as a cross-section of port infrastructure investments, cost of maritime transport, and port competitiveness. The rest of the study is structured as follows: Section 2 reviews the literature on the importance of port infrastructure development and port competitiveness factors. In Section 3, the research methodology is described. Section 4 analyses the impact of port infrastructure investments on cargo transport costs and supply security, and consequently on the port competitiveness in the opinion of shippers. Finally, Section 5 contains conclusions with elements of discussion with previous results.

2. Literature Review

The research carried out for the purposes of this study combines two streams that are continuously addressed in the literature on seaport economics. The first of them is about decisions on new investments in port infrastructures and their impact on port functioning. These decisions can be seen as strategic decisions affecting the operation of the port in subsequent years. The second one is the area of port competitiveness in the context of possible changes in shippers' decisions concerning the choice of port-oriented supply chains. The decision process involves answering a number of questions and finding a rational explanation supported by economic calculation and considering specific conditions [8].

Investments in the port infrastructure cover, i.a., land reclamation works, capital dredging and maintenance dredging, on-terminal rail facilities, roads on the terminal, quay-wall construction and maintenance, mooring equipment, and fenders [9]. Decisions regarding implementation of investments in port infrastructure and improvement of port accessibility represent a complex and multi-faceted issue. It is beyond doubt that appropriate infrastructure is one of the factors that contribute to port development and improving its attractiveness [10]. However, to make a decision on new investments, it is necessary to take a balanced approach and to realistically assess the expected benefits, as there have been cases when costly investments in port infrastructures led to a considerable rise in port fees, which in the port users' opinion contributed to a decrease in its attractiveness [11]. An excessive investment in a port infrastructure, which considerably exceeds the needs represented by the cargo volumes handled by the port, contributes to overcapacity of the port system and consequently to difficulties in port management [12].

A significant number of research studies dedicated to issues of port infrastructure development and port-related transport systems have focused on effects and benefits for national economies [13], regional economies [14,15], and port cities [16,17]. The research often takes the form of a case study, and it covers only a single port or ports located within a specific area. In principle, the positive impact of port infrastructure investments on increasing the trade volume is emphasised [18]. For example, the research studies carried out for Brazilian ports have shown that an increase in port infrastructure is associated with large increases in Brazilian exports [19]. At the same time, it is possible to identify some negative effects of the spatial expansion of port infrastructure and conflicts of interest between the port and the port city [20], as well as uneven shares in the benefits ensuing from the port development, perceived by various stakeholder groups [21].

A pre-requisite for any port development is good connectivity with the hinterland transport system and appropriate maritime accessibility. The vast majority of research studies dedicated to issues regarding the relationship between any given port's attractiveness and its infrastructure development analyse the infrastructural investments that facilitate access to the port from the land side, and development of the transport network in the port's hinterland [22,23]. It is also stressed that even though traditionally the distance from the port was considered the parameter that reflected the economic impact of a seaport on the land, currently a fundamental role is played by the effectiveness of inland connections [24,25].

Nautical (or maritime) accessibility is understood as the physical capacity of a port to serve larger vessels and accommodate ship operations regardless of weather and tidal conditions [26,27]. The issues of port infrastructure development in order to improve its nautical accessibility are most often found in technical studies, usually in the context of navigation safety, improving the navigation conditions or waterway management [28]. The current area of study is making use of infrastructural investments to adapt to climate changes [29,30] and to address sustainability issues [31]. The more often raised issues also include environmental impacts and social effects related to dredging operations [32]. Investment projects implemented in ports often combine several aspects, e.g., connectivity, security, environmental sustainability, digitalisation [33], and IT infrastructure [34]. However, in the literature there are relatively few studies regarding the impact of improving the fairway depth on the given port's attractiveness in economic terms and in view of managerial benefits for business entities.

An example of a study focusing on the issues of maintaining or increasing the fairway depth in the business and management context is the article authored by Canel [35] and dedicated to the port in Hamburg. The port is located on the Elbe river ca. 110 km from its North Sea estuary. The maximum draught parameters of vessels handled in the port depend on the fairway depth, and the situation is additionally affected by tides [36]. Refraining from deepening the fairway may prevent large container ships from calling at the Hamburg port, as they would choose other competitive ports from the North Range, which can consequently lead to losing jobs as a result of decreased transshipment volumes and also to losses sustained by the domestic economy in the form of reduced national gross value added, income, and tax payments [35]. In Europe, similar problems connected with the need to deepen the maritime access infrastructure can be identified, e.g., in the Bremen port which for years was losing the competition for containerised cargo with the port in Bremerhaven. Both ports are situated on the Weser River, the port in Bremerhaven is located at its North Sea estuary, while the port in Bremen is ca. 60 km upstream. The deep-water terminals in the Bremerhaven port took over the handling of large container ships, whereas the port in Bremen serves vessels characterised by smaller draughts [37].

The studies completed so far with regard to expected results of improving the maritime access to the port in Szczecin were conducted in order to assess the possible increase in transshipment volumes and its outcomes in the form or reduced transport costs for vessel owners, lower external costs for the individual transport modes, as well as an increase in the gross value produced by port activities [38]. However, the studies did not tackle the following questions: to what extent are the implemented investments attractive to shippers in financial terms, and may such investments lead to changes in decisions regarding the choice of port?

Outcomes of implementing port infrastructure investments have not yet been sufficiently examined in terms of attractiveness for shippers, and accordingly in view of a potential reconfiguration of port-oriented supply chains. The research studies dedicated to those issues differ in terms of the adopted research framework, methods applied, specific research objectives, and the spatial scope. For instance, the study authored by Lee et al. [39] analysed the potential changes in port choices made by shippers as a result of the planned port entrance channel dredging of Incheon New Port in South Korea. That study focused on developing an econometric method for estimating the cargo volume that can be shifted to the port from the competing ports. Vandenberg and Canales [40], in turn, analysed the possible investments in the port and transport infrastructure in North Carolina, USA, and their expected economic effects for selected industries, in order to form an optimal maritime strategy for that State. Their attention was focused on investment costs and future demand forecast; however, any costs to be incurred by shippers using the new solutions were not analysed. Tian et al. [41] showed that development of port infrastructures has a long-run effect on port handling capacity in the 14 researched Chinese ports, where increasing the construction of large appropriate deep-water berths was of key importance. Their article underlines the positive role of the port infrastructure development; however, it did not analyse any sample supply chains or incurred transport costs. Moreover, the study authored by Vega et al. is worth noting [42]. Even though the analysed scenarios of potential investments focused on the hinterland of Colombian ports rather than investments within the ports, the article emphasises that some draught-related problems affect the reliability of the port operations, hence the extreme importance of investments focused on dredging and hydraulic activities for maintaining the draught adequacy.

Some researchers noted that shippers pay attention not only to business aspects, but also to psychological issues. It is beyond doubt that any possible modification of a shipper's decision regarding choice of port is a process which requires time as well as change in attitude and habits. Jiannan et al. [7] argued that increased satisfaction resulting from new port investments was weaker than habits developed once the port was chosen as well as the loyalty to the port, and an increased interest in their service offer may be enjoyed mainly by the ports which have won shippers' loyalty prior to commencing new investments.

Appropriate maritime access to the port is an important factor in analyses regarding choice of port and port competitiveness. This stream of research concentrates on identifying and then hierarchizing major factors that determine the competitive position and consequently the choice of port by individual groups of port users. Drawing up a complete list and ranking of the factors has continuously been an object of research studies. Sets of factors of competitiveness are developed in general terms or from the perspective of specific terminals and port users: shippers, forwarders, shipping lines, shipping agents, and logistics operators. Research studies in the area of port competitiveness and port choice from the perspective of the shippers were carried out by, e.g., Steven and Corsi [43], Nazemzadeh and Vanelslander [44], De Langen [45]; Kashiha et al. [46]; and Nugroho et al. [47]. New, interesting grounds for taking up further research keep coming up. For example, attention is drawn to the fact that shippers are not a homogeneous group, and their preferences regarding choice of port depend, i.a., on the industry they represent, and the type of foreland to which they send their cargoes [48]. Moreover, the importance of the factors depends on the size of the shipper. The smaller ones pay more attention to the ocean transport costs of shipment, whereas the bigger ones tend to focus on factors that enable more rapid transport of their cargoes [43]. The perspective of a shipper was also adopted in the research study described in this study.

The key drivers of port competitiveness which are identified in many research studies as significant to all port users include several groups of factors: port costs, hinterland proximity, hinterland connectivity, port geographical location, port infrastructures, operational efficiency, port service quality, maritime connectivity, nautical accessibility, and port site [49]. Two of them, port infrastructure and nautical accessibility, are addressed in this study. Their considerable importance is confirmed in many studies in the area of port competitiveness. Some of the articles do not further specify the factors from the two thematic areas, whereas others subdivide them. For example, Tongzon and Heng [50] placed depth of the navigation channel among the eight major port competitiveness determinants. Yeo et al. [51] included water depth in approach channels and at berth to the factor group named convenience. In the case of a hinterland shared by two ports, a competitive advantage may be claimed by one of them, i.a., due to its natural endowments (particularly depth of water) and quality of service improvements that are the result of enhancements to inland transport infrastructure and logistic systems [52]. Analysing major determinants of port competitiveness, Dyck and Ismael [53] proposed eight factor groups that included, i.a., port infrastructure. It is described by means of attributes such as water depth (permissible draughts for vessels under full load), linear berth length, and terminal size.

Port infrastructure and facilities are considered to be critical assets that are decisive for the port attractiveness. These are hard resources that are necessary to perform both port and value-added logistics activities, whereas factors such as, e.g., services, inter-organisational relationships between port stakeholders, and communication systems, are described as soft components of competitiveness [54]. The literature also identifies an approach where comparisons and port choice decisions should involve not only ports themselves, but the whole port-oriented supply chains [55]. Based on this approach, this study takes into account transport costs in a supply chain for both the sea and land legs. Even though the literature shows the significance of various competitiveness factors, and the proposed rankings of importance not always provide the same results, it is stressed that the factors under the control of port authorities, such as port performance or port connectivity, are the main factors for port selection, which means that port authorities can improve in some way their competitiveness through the design of competitive strategies and investments [56]. The factors examined in this study, i.e., investments in fairway deepening and the accompanying investments in the port infrastructure, should be included in this very group of factors.

A detailed evaluation of the impact of port infrastructure development on shippers' decisions still requires in-depth research. Even though in many articles port infrastructure and nautical accessibility tend to be unambiguously considered to be significant factors of port competitiveness, not all authors place them on the top of the list. For example, for Talley [57] the most important factors that determine the choice of port by shippers are: port money prices, port characteristics, and ship-schedule characteristics of ships that call at the port. The term 'port characteristics' here is understood as the distance between the origin inland location of the cargo and the location of the port, the water distance from the port to the cargo's destination port, and the time that the cargo remains in the port. Nautical accessibility was not included in the group. Some studies identify competitiveness factors such as, e.g., port location or natural factors [58], which may be associated with nautical accessibility without restricting to this determinant as such.

Evaluations of port competitiveness more and more often emphasises the significance of factors such as security, conditions stability, and service dependability in the port. The significant factors also include reliability [50,59] and port reputation [60]. It is stressed that security and reliability of the supply chain influence the level of efficiency, and one poorly functioning link in the chain can lead to delays and consequently to losing port clients [48]. Port-related supply chain disruption threats ensue from, among other things, inappropriate port infrastructure [61]. Efficient and modern seaports with their physical infrastructures that enable handling an increasing number of increasingly larger ships are important for reducing delays in supply chains [62]. An appropriately high level of factors such as service level [26] and assuring reliability of delivery [63] tend to be indicated as more important than price competition between ports. The research studies covering American ports have shown that a lack of safe and stable deliveries caused by port congestion and delays is a sufficient hindrance that may make shippers change their decisions on choice of port to the effect that the price is no longer their primary decision factor [64].

3. Methods

An analysis of the existing research literature showed that improvement of seaport access parameters is a significant factor of port competitiveness. However, so far there have been no studies describing the scale of benefits for cargo shippers who organise the whole transport chain. This study aims at demonstrating the impact of fairway deepening on port-oriented supply chain costs and security of supply, as well as verification of the importance of these factors to cargo shippers. To reach this aim, the Single Case Study Design method was applied [65] as well as qualitative and quantitative research techniques (Figure 1).

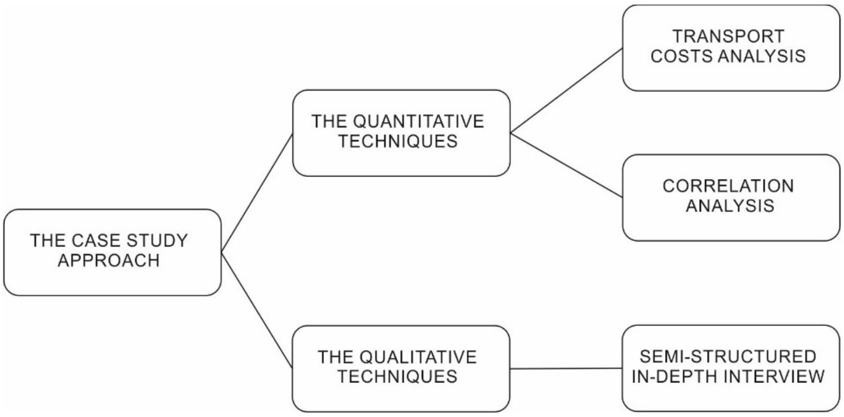

Figure 1. Research method and techniques.

In accordance with the SCS method principles, four research questions were formulated:

1. Will the investment in the seaport access infrastructure (i.e., the fairway deepening) bring benefits to cargo shippers, and on what scale?
2. May the fairway deepening lead to increasing the share of cargoes to/from the port's distant (extra-European) foreland?
3. May the port infrastructure investments contribute to improving the security of sea-land supply chains?
4. Which additional factors must be met in order to improve the port's attractiveness for cargo shippers?

Based on the questions, the following proposal was stated: investments in port access infrastructures have an impact on decreasing the total cost of port-oriented supply chains and improving the supply security, thus contributing to increasing the transshipment volumes in the port and to changing the port's foreland structure. The next step in designing the SCS method was defining the unit of analysis.

The study covered the seaport in Szczecin, which is one of the four major Polish seaports (in addition to the ports in Gdynia, Gdańsk, and Świnoujście) of primary significance for the national economy. As opposed to the other seaports, the port in Szczecin is located 70 km upstream the Oder River (Figure 2). For many years, this location was considered very advantageous due to offering shorter distances to business facilities located in the hinterland; however, this factor has recently been losing its significance. The changes taking place in the world maritime transport have led to gradual weakening of its competitive position as a result of inferior possibilities of vessel handling in comparison with the other ports. In theory, the port in Szczecin may handle vessels with a draught of up to 9.15 m or with a length of up to 215 m; however, in practice the longest ships may have a draught of below 8.5 m, and those with the maximum draught may be up to 160 m in length. Therefore, the port serves ships with a capacity below 20 k DWT. This is considerably less than in the case of the other Polish ports which handle vessels with a draught of 13 m in Gdynia and 15 m in Gdańsk (including Baltimax ships with a capacity of 150 DWT). In exceptional cases, the harbour master in the Szczecin port may consent to handling larger ships, where such consent depends on the current conditions in the fairway, which significantly reduces the reliability and security of deliveries made within supply chains. Planning any transport that involves vessels with the maximum parameters allowed for the port in Szczecin bears a considerable risk, which is taken by shippers only in exceptional situations.

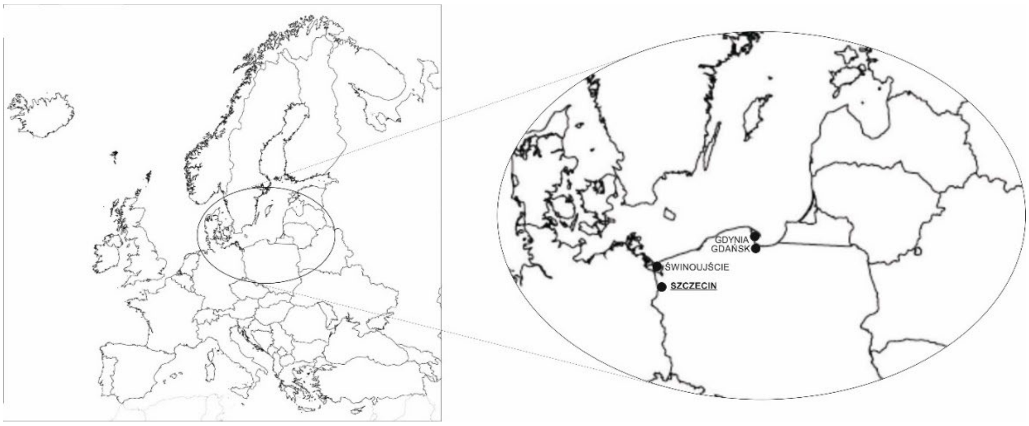

Figure 2. The location of the port in Szczecin.

The competitive position of the Szczecin port has deteriorated in recent years. The effects can be noticed in the port's transshipment volume and its structure of cargo flows. Over the past 10 years, the transshipment volumes in the Polish seaports have risen by over 50%, whereas in the Szczecin port the value has increased only slightly above 10%. At the same time, extra-European markets have gained importance (twofold increase in total transshipment volume); however, the Szczecin port did not benefit from that trend. Its share in serving the extra-European foreland has almost halved (Table 1).

Table 1. Polish major seaports, their transshipment volumes, and shares of the extra-European foreland in their international maritime trade in 2010 and 2020 (k tonnes).

Characteristic		Total	Gdańsk	Gdynia	Szczecin	Świnoujście
		2010				
Total	k tonnes	59,506.5	26,421.2	12,346.1	7969.2	10,682.7
	%	100.0%	44.4%	20.7%	13.4%	18.0%
Europe	k tonnes	46,976.0	21,177.3	10,543.5	6916.8	7378.5
	%	100.0%	45.1%	22.4%	14.7%	15.7%
Extra-European foreland	k tonnes	12,530.5	5243.9	1802.6	1052.4	3304.2
	%	100.0%	41.8%	14.4%	8.4%	26.4%
		2020				
Total	k tonnes	85,737.7	39,497.6	20,928.7	8801.0	14,488.1
	%	100.0%	46.1%	24.4%	10.3%	16.9%
Europe	k tonnes	57,185.0	25,065.1	14,503.6	7389.7	9178.1
	%	100.0%	43.8%	25.4%	12.9%	16.0%
Extra-European foreland	k tonnes	28,552.7	14,432.5	6425.1	1411.3	5310.0
	%	100.0%	50.5%	22.5%	4.9%	18.6%

Source: Own study based on the data provided by [66,67].

This is the effect of the changes taking place in the world fleet structure. Considering the parameters of new bulk carriers or container ships, their average tonnage exceeds ca. four times the parameters of fully loaded vessels that are now able to enter the port in Szczecin. Therefore, in 2017 a decision was taken to dredge the fairway and the port basins up to 12.5 m, which will make it possible to double the carrying capacity of vessels entering the port. As a result, the port will be able to handle Handymax vessels, and even not fully loaded Panamax ships with a draught of up to 11.5 m and length of up to 230 m, regardless of the weather conditions and without a special permit for port handling.

In order to answer Question 1, i.e., "will the investment in the seaport access infrastructure (i.e., the fairway deepening) bring benefits to cargo shippers, and on what scale?", a comparative analysis of transport costs was carried out for five sample transport chains, of which three regarded imports, and two regarded exports. The selected routes and cargoes represent the potential transactions made via the port in Szczecin. Within each single route, the same conditions were assumed for the land transport leg, whereas the maritime leg of the chain was analysed in three scenarios depending on the size of the vessel applied. The first scenario (W0) describes the situation prior to the deepening of the Świnoujście–Szczecin fairway. The assumption was that cargoes would be carried by vessels with a capacity of ca. 20 k tonnes and a draught of 8.5 m (Handysize). In the second scenario (W1), following the deepening of the Świnoujście–Szczecin fairway, the assumed vessel capacity was 40 k tonnes (Handymax). Additionally, in the case of two cargoes with the highest stowage factors, the calculation also included the cost of transport with a Panamax vessel (80 k DWT), which was the third scenario (W2) (Table 2).

Table 2. Ship parameters included in the analysis.

Ship Parameter	Before Dredging	After Dredging	
	Variant W0 Handysize	**Variant W1 Handymax**	**Variant W2 Panamax**
Deadweight	19,124 t	39,072 t	79,649 t
Length overall	140 m	180 m	229 m
Breadth	25.1 m	30 m	32.2 m
Draught	8.5 m	10.5 m	14.6 m
Grain capacity	23,161 m^3	51,288 m^3	97,000 m^3
Bale capacity	22,563 m^3	48,918 m^3	90,784 m^3
Fuel consumption	19.5 Mg/day	18 Mg/day	39 Mg/day

Methodological assumptions adopted in the analysis:

- The following routes were covered by the analysis:
    - Route I: Imports. Transport of metal sheet coils Route: Mumbai (India)–Szczecin–Kluczbork;
    - Route II. Imports. Transport of chemical fertilisers in bulk. Route: Shanghai (China)–Szczecin–Wrocław;
    - Route III. Imports. Transport of soybean meal in bulk. Route: Salvador (Brazil)–Szczecin–Nowa Sól;
    - Route IV. Exports. Transport of coke. Route: Zdzieszowice–Szczecin–Trieste (Italy);
    - Route V. Exports. Transport of wheat in bulk. Route: Grodzisk Wlkp.–Szczecin–Casablanca (Morocco).

Each calculation takes into account: the cost of maritime transport, cost of transshipment in the port, and cost of land transport. The land transport leg makes use of road or rail haulage, depending on the route.

- In the case of imports, the analysed transport chains start in a port of loading. In the case of exports, the transport chains end in ports of unloading. The analysis covered: the cost of maritime transport, the cost of transshipment in Szczecin, and the cost of land transport within the territory of Poland;
- Fuel prices VLSFO/MGO/IF380 (Rotterdam): 305/330/255 USD/tonne (permissible fluctuation +/− 10–15%);
- The costs of maritime carriage also included the brokerage fees as well as tonnage, mooring, and pilot and hauling charges;
- As for the port handling operations, intermediate transshipment was assumed, as well as storing the cargoes only in the free storage period. That period is specified differently, depending on the terminal;
- The freight rates in maritime carriage, transport rates in land transport, and transshipment rates adopted in the calculations were binding in September 2020;

- The data necessary for carrying out the computations were sourced during the interviews with ship brokers and forwarders, in addition to that, the sources also included Railway Freight Tariff of PKP Cargo S.A. (rates on 1 January 2020), PKP Cargo S.A. Catalogue of Wagons and List of PKP Railway Tariff Distances.

In order to answer Question 2, i.e., *"May the fairway deepening lead to increasing the share of cargoes to/from the port's distant (extra-European) foreland?"*, it was necessary to analyse the research results being the sea freight costs for the analysed routes. To that end, a correlation was determined between sea distance (D) and benefits for cargo shippers, which ensued from a reduction in port-oriented supply chain costs (the analysis accounted for Variants W0 and W1). In view of the considerable dynamics of the maritime freight rates, the analysis was based on relative values. Benefits (B_i) for each variant i were determined in % as per the formula:

$$B_i = \frac{CB_i - CA_i}{CB_i} * 100\%$$

where CB_i is the maritime transport cost per tonne in variant *i* prior to the fairway dredging, and CA_i is the maritime transport cost per tonne in variant *i* after the fairway dredging.

The results are presented in the form of Graph $B_i = f$(D).

At the next stage of the research study, direct interviews were held with selected representatives of cargo shippers served in the Szczecin port. The purpose of conducting the direct interviews was:

- To validate the quantitative studies results (confirmation of the 1st and the 2nd research questions);
- To provide an answer to the 3rd and the 4th research questions: "may the investments in the port infrastructure contribute to improving the security of sea-land supply chains?" and "which additional factors must be met in order to improve the port's attractiveness for cargo shippers?".

The respondents were selected on a targeted basis to obtain responses from representatives of each of the cargo groups served in the port. As part of the validation of the obtained research results, the interviews were held with representatives of five shippers involved in the export/import of cargoes addressed in the main study, i.e., steel semi-finished products, chemicals (including fertilisers), soybean meal, coke, and grain (mainly wheat). The interviewees were the shippers who, according to the statistics of the Polish National Customs Administration, generated minimum 10 k tonnes of cargoes in Poland's maritime exports or imports. Out of them:

- Four currently use transshipment services in the Szczecin port (of which three also use the services of other Polish seaports);
- One currently does not use transshipment services in the Szczecin port (but used them in the past and does not exclude a possibility of using them in future).

The general characteristics of the interviewed shippers and their related sea-land supply chains are shown in Table 3.

Table 3. General characteristics of the interviewed shippers and sea-land supply chains served by them.

Shipper	Type of Cargo	Cargo Flow Direction	Foreland	Type of Shipper	Representative
A	Conventional; steel semi-products, (cold and hot rolled steel)	Import	Europe, Asia	Manufacturer	Logistics manager
B	Conventional, containerised; chemicals	Import	Dispersed, i.a., Asia	A trader with their own storage facilities in Szczecin	Quality and Logistics Manager
C	Conventional; soybean meal	Import	South America	A trader with their own port terminal in Szczecin	Terminal Manager
D	Conventional, containerised; coke	Export	Europe, Asia, Africa	Trader	Sales and Marketing Director
E	Conventional; grain	Export	Mainly Africa	A trader with their own port terminal in Szczecin	Terminal Manager

4. Results

4.1. Benefits for Cargo Shippers—An Analysis of Transport Costs

The results of the cost analysis run for all the contemplated routes and variants are presented in Figure 3. The detailed input data and results are shown in Supplementary Materials. The results are as follows:

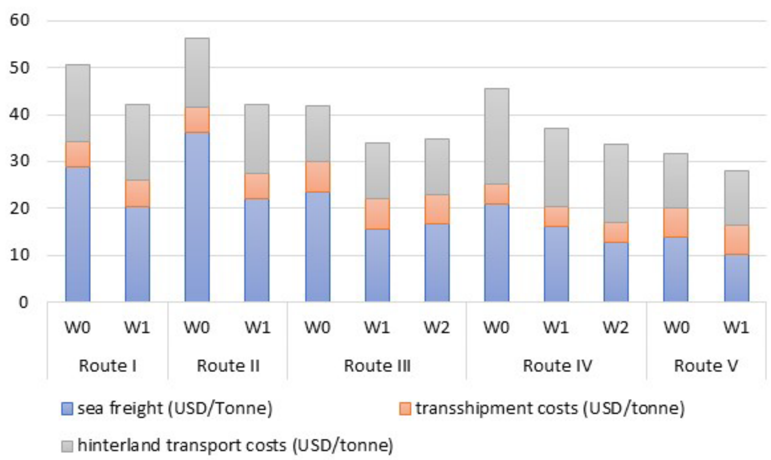

Figure 3. Transport costs for the analysed routes prior to and after the fairway dredging.

1. Route I. Imports. Transport of metal sheet coils Route: Mumbai (India)–Szczecin–Kluczbork (via Suez Canal; pre-haulage–road transport)

The analysis showed that the total route cost in Variant W1 (after the fairway dredging) is lower by 16% than in Variant W0 (prior to the dredging); what is more, the maritime carriage itself costs as much as 29% less (Figure 4). It is also interesting to compare the shares of the individual cost constituents for both vessel sizes. The biggest share in the costs accounts for the cost incurred in the maritime leg of the chain. A decision to apply a bigger vessel results in decreasing the share of the sea freight cost in the total freight cost from 57% to 48.5%.

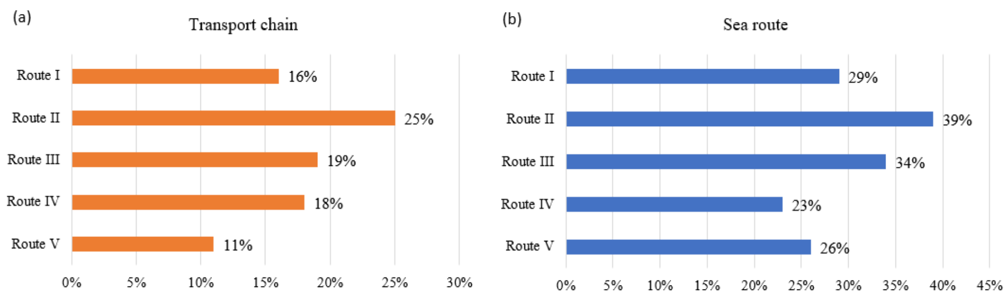

Figure 4. Cost differences between Variants W0 and W1 for all the analysed routes (based on the data as of September 2020) in relation to transport chain (**a**) and sea route (**b**).

2. Route II. Imports. Transport of chemical fertilisers in bulk. Route: Shanghai (China)–Szczecin–Wrocław (pre-haulage road transport)

Similarly, as for Route I, also in this case, sea freight with a larger vessel translates into lower freight unit costs over the whole transport chain. On Route II, transporting one tonne of cargo is less expensive by 25% in the case of applying a vessel with a bigger capacity. The reason for such a considerable spread between the freight unit costs over the whole route is the significant difference between freight rates for 20 k DWT and 40 k DWT vessels. The freight rate for bigger vessels, on conditions adopted for Route II, is as much as 39% lower than the freight rate binding for the smaller vessel.

The analysis of the shares of the individual cost groups comprising the total freight cost shows that for Route II the sea freight cost accounts for as much as 64% of all costs in the scenario implemented for a 20 k DWT vessel (W0). This is the highest result among all the analysed variants. In the case of W1 the share drops to 52.5%.

3. Route III. Imports. Transport of soybean meal in bulk. Route: Salvador (Brazil)–Szczecin–Nowa Sól (pre-haulage road transport)

For the land transport leg, road haulage was applied. Moreover, in this case transport of one tonne of cargo is the most expensive in Variant W0. Interestingly, the cheapest variant does not regard the largest ship. In this case, the cost of carriage with a Panamax vessel (W2) is slightly (3%) higher than with a Handymax ship (W1). In the analysed transport route, the ship handling costs in ports (tonnage dues) translated into higher costs of Panamax vessel (W2). Ship handling costs in ports differ depending on the vessel size and tonnage. A decision regarding use of a Panamax ship should each time be preceded by checking the ship handling costs in the port, as it may turn out that high handling costs related to a larger ship exceed any potential economies of scale, which can be achieved by using a higher capacity vessel. In view of the adopted assumptions, the optimum variant is W1.

In all the analysed transport variants, the reasons for the varied freight unit costs are the different levels of freight rates. For Route III, the freight rate for transport with a Handymax ship is by 34% lower than the freight rate for a Handysize one.

The analysis of the shares of the individual cost groups in the total freight cost shows that the sea freight cost accounts for as much as 56.6% of all the costs in the scenario implemented for Variant W0, and 46.1% for W1. In the case of Variant W2, due to the higher freight rate compared with Variant W1, the share amounts to 47.7%.

4. Route IV. Exports. Transport of coke. Route: Zdzieszowice–Szczecin–Trieste (Italy) (pre-haulage rail transport)

For this transport route, the freight unit costs become lower and lower as larger and larger ships are applied. Compared with Variant W0, the transport cost per tonne of cargo is 18% lower in Variant W1 and 26% lower in Variant W2. The differences ensue from a considerably wide range of freight rates for particular vessel groups. For conditions adopted for Route IV the optimal variant is Variant W2.

5. Route V. Exports. Transport of wheat in bulk. Route: Grodzisk Wlkp.–Szczecin–Casablanca (Morocco) (pre-haulage road transport)

On this route, the most competitive variant in terms of pricing is W1. When applying a Handymax vessel, the freight unit cost throughout the transport chain is lower by 11% compared with transport with a Handysize ship. Similarly, as in the previous variants, this is due to the differences in freight rates, to the advantage of using a Handymax ship. In this case, the freight rate for a Handymax vessel is lower by 26% in comparison with a Handysize one. In Variant W0, the share of the sea freight cost in the total freight cost amounts to 43.7%, whereas in Variant W1 it drops to 36.4%.

To sum, in each of the studied variants the more competitive scenario was the one where a Handymax vessel was used instead of a Handysize one. The cost of carrying one tonne of cargo over the whole transport chain was in each case lower in the case of a Handymax bulk carrier compared with a Handysize vessel, and the differences ranged from 11% to 25% depending on the route (Figure 4a). The diverse costs of cargo shipping result from the considerably wide range of freight rates between Handysize and Handymax ships. In each case, the freight rates are lower for 40 k DWT vessels, and the cost advantage ranged from 23% to as much as 39%, depending on the route (Figure 4b).

At the same time, it should be noted that this regularity does not always hold, i.e., freight rates not necessarily go down as the carrying capacity of vessels applied on the routes goes up. For Route IV, the most advantageous solution is to apply a Panamax ship, and the cost advantage over the whole transport route amounts to as much as 26% in comparison with a 20 k DWT vessel. However, in the case of Route III this regularity does not hold, in this case the optimum solution is to employ a Handymax vessel.

The presented calculations show that making use of Handymax ships with a draught of 11 m, on the adopted conditions, is more cost-competitive in comparison with Handysize vessels with a smaller draught. However, application of ships of the Panamax type first requires checking the financial conditions for the given route, connected with the ship handling costs at the port, so as to make the best decision concerning selection of an optimum vessel. Adapting the Szczecin seaport so that it can be called by vessels with a draught of 11 m will make it possible for cargo shippers to avail themselves of the competitive advantage in the form of considerably lower costs of cargo freight, which should contribute to increasing the volume of transshipment in the port, particularly with regard to vessels coming from the distant foreland.

4.2. Assessing the Possibility of Changing the Port's Foreland Structure–Correlation between the Maritime Distance and Costs

The analysis presented in item 4.1 was developed based on freight rates valid in September 2020. Even though since that time the freight rates have been subject to considerable fluctuations, the fact is that the fluctuations concern all the types of the analysed vessels. In effect, the freight rate ratios between Handysize:Handymax:Panamax vessels are maintained on a relatively stable level and they are independent from the economic situation on water-borne transport markets. In view of the above, the assessment of the possibilities of changing the foreland structure was based on relative values.

The correlation analysis showed a considerable dependency between maritime shipping distance and relative costs of maritime transport (correlation coefficient of 0.85). This justifies formulation of another thesis: the longer the transport route, the bigger the relative (in %) benefits for cargo shippers (Figure 5). In the case of using a Handymax ship instead of a Handysize one, the benefits (Bi) amount from 25% for a route within Europe (2000 Nm) to 40% for an oceanic route (12,000 Nm). The benefits ensuing from shifting cargoes to the port in Szczecin are much bigger for the cargo shippers using oceanic shipping routes, compared with those achieved by shippers working on European routes. Therefore, it is possible to presume that the fairway deepening will have a positive effect on the foreland structure of the Szczecin port: the share of the distant (extra-European) foreland will increase at the expense of the close foreland, thus approaching the structure observed in other Polish seaports.

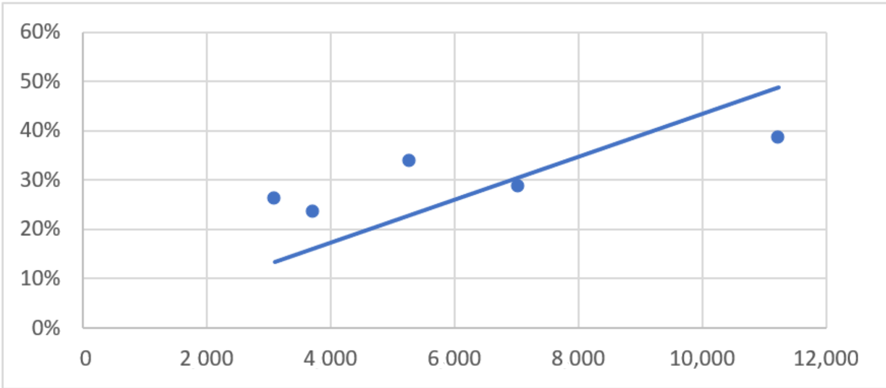

Figure 5. Dependency between relative benefits Bi for cargo shippers, ensuing from reducing the freight costs (OY axis), and maritime shipping distance (OX axis).

4.3. Direct Interviews

The purpose of the next stage of the research was firstly validation of the quantitative studies (confirming the benefits for cargo shippers and change in the foreland structure), and secondly providing answers to the remaining two research questions. The completed interviews made it possible to draw the following conclusions regarding the research questions:

1. Will the investment in the seaport access infrastructure (i.e., the fairway deepening) bring benefits to cargo shippers, and on what scale?

Most shippers provided positive answers to this question, and declared increased annual transshipment volumes in Szczecin after the fairway was deepened. Based on the interviews held, the following scenarios were identified:

- Unquestionable increase in transshipments made so far in the Szczecin port (C, E);
- Expected increase in transshipments in Szczecin, including both cargoes handled so far, as well as new ones or cargoes coming from the foreland that have not hitherto been served (B);
- Potential possibility of shifting to Szczecin the totality of transshipments currently made in another seaport (competitor to the Szczecin seaport) (D);
- The transshipments made so far in Szczecin will not increase due to price instability concerning imported cargoes, limited own storage capacity of the shipper, and limited budget for purchases at the moment (A).

2. May the fairway deepening lead to increasing the share of cargoes to/from the port's distant (extra-European) foreland?

Most of the interviewees confirmed that following the dredging of the fairway to the Szczecin seaport to the depth of up to 12.5 m, the share of cargoes originating from/destined to the extra-European foreland would rise. The supporting arguments included:

- No need to lighten the ships in other southern Baltic seaports to transport cargoes carried from the extra-European foreland to the port in Szczecin (C);
- No need to top the ships in other southern Baltic seaports to transport cargoes carried to the extra-European foreland from the port in Szczecin (E);
- Handling cargoes coming from the extra-European foreland which have not hitherto been served by the Szczecin seaport, as a result of meeting the so-called logistic minima for their transport by sea (B);
- Unitised cargoes, which have so far been shipped to the extra-European foreland via other southern Baltic seaports, will be able to be handled in the Szczecin seaport (D).

3. May the port infrastructure investments contribute to improving the security of sea-land supply chains?

According to the representatives of the interviewed shippers, dredging the Szczecin seaport fairway up to 12.5 m will contribute to improving the security of the supply chains of the contemplated cargoes, as a result of:

- Possibility of handling one-off consignments in the shipper's own terminal in the Szczecin port, as they do not need to use third-party terminals located in other seaports, thus minimising the risk of delay in loading/unloading and consequently the risk of disruptions in the whole supply chain (C, E);
- Providing by the Szczecin port conditions that offer any given shipper flexible possibilities of implementing various supply chain scenarios (various directions, various transport technologies; conventional/containerised) (D);
- Providing shippers with the possibility of making use of the new depths of the Szczecin port in an unexpected situation when it is necessary to change the supply markets to those more distant geographically (e.g., as a result of imposing an embargo on supplies from a specific country) (A);
- A decreased risk that any terminals located in the foreland of the Szczecin port might refuse to load any one-off consignments onto ships due to their size (B).

4. Which additional factors must be met in order to improve the port's attractiveness for cargo shippers?

According to the representatives of the interviewed shippers, the dredging of the Szczecin port fairway up to 12.5 m is an investment of key importance in terms of making the port's service offer more attractive. However, in addition to the deepening of the fairway, there are other conditions to be met before the entities decide to increase the transshipment volume in the Szczecin port or to shift the cargoes hitherto transported via other seaports to any supply chains running through Szczecin. These are:

1. Upgrading the quays and adjusting them to the new depths of the fairway;
2. Investments in the port handling equipment (increasing the equipment capacity) and storage facilities;
3. Running promotional campaigns during trade events attended by shippers in order to publicise the capability of the Szczecin port to handle higher capacity vessels and the possibility for shippers to locate their own terminals on the port's grounds;
4. Development of container ship connections from/to Szczecin, handled by transoceanic operators, with a freight fee for feeder ship transport included in the overall rate for sea freight.

In addition, the impact of the 12.5 m depth on handling in Szczecin according to the representatives of the interviewed shippers is presented in Table 4.

Table 4. The impact of the 12.5 m depth on handling in Szczecin.

Shipper	Handling Seaport (PL)	Reasons for Using Seaports Other Than Szczecin	Assessing the Impact of the 12.5 m Depth on Handling in Szczecin	Other Indispensable Measures, Apart from 12.5 m Depth
A	Szczecin	• Do not use other ports	Constant	none
B	Szczecin (bulk), Gdynia (containers)	• Carrying capacity of Szczecinmax ships is too low; • Problems with manoeuvring the ships on the fairway; • Lack of extended storage facilities for liquid cargoes; • A modest range of container ship connections	Expected growth	1, 2, 3
C	Szczecin, Gdynia	• Carrying capacity of Szczecinmax ships is too low	Growth	1
D	Gdańsk	• Lack of a well-developed network of feeder connections	Possibility of shifting all	1, 2, 4

			transshipments to the Szczecin port	
E	Szczecin, Świnoujście	• Carrying capacity of Szczecinmax ships is too low	Growth	1, 2

5. Discussion

The outcomes of our research made it possible to verify and extend the studies completed so far regarding the importance of port infrastructure investments for the port stakeholders, particularly cargo shippers.

This study demonstrated that in a vast majority of cases making deliveries with larger ships translates into decreasing the freight unit costs. Our research showed that a 2.5 m increase in the permissible draught of ships results in a decrease of up to 25% in transport costs throughout the chain. Nevertheless, the final transport decision should be preceded by a thorough calculation of costs, as in some cases making use of a larger vessel (such as a Panamax ship in our study) will not be the most advantageous solution for cargo shippers. This depends on the transport route and the physical properties of the cargo (and stowage factor in the first place).

Lower transport costs translate into an increased interest in the port and shippers' propensity to shift between transport chains. Thus, we confirmed the results of the previous studies, i.a., those by Parola et al. [49], Talley [57], Tongzon and Heng [50], Kaliszewski et al. [59], Kotowska et al. [63] stating that one of the major factors for cargo shippers is the cost of delivery in a port-oriented supply chain.

Our study also confirmed the results of the previous research by Tongzon [10] who noted that appropriate infrastructure is one of the factors contributing to development of a port and improving its competitiveness. We also confirmed the studies by Liu [18] and Bottasso et al. [19] who drew attention to the potential growth in trading as a result of port infrastructure investments. The uniqueness of our studies consisted in the quantification of the benefits. So far, there have been no studies that estimated direct benefits for cargo shippers as a result of the fairway deepening; moreover, the dependencies between the benefits amounts and the transport chain lengths have not been demonstrated.

Our research study showed a directly proportional dependency between the benefits (resulting from decreased transport costs) and the transport distance: the longer the transport distance, the bigger the benefits. The study made it possible to formulate a thesis that the fairway deepening may have an impact on changing the port's foreland structure. This thesis was confirmed in the direct interviews held with cargo shippers. The shippers indicated the fact that as a result of the deepening there will no longer be a need to lighten or top the ships in other European ports, and the possibility of handling larger ships, will enable them to meet the so-called logistic minima for extra-European cargoes.

The interviews we conducted confirmed the studies authored by Martínez-Moya and Feo-Valero [48], who indicated the major impact of the foreland size (as represented by regular shipping lines) on the port attractiveness. Our study also showed that the factors that are equally important to cargo shippers include adjusting the port quays to the new depths, increasing the efficiency of transshipment equipment (loading/discharge rates), and storage space.

The study also validated the deliberations of Jiannan et al. [7] who said that changing the transport chains by cargo shippers is a long process that requires time and a change in attitude and habits. What is more, our study additionally revealed a major problem: cargo shippers do not have knowledge about new possibilities; therefore, it is important to adequately propagate the information on the investments among potential stakeholders of the port. It is also vital that port authorities create possibilities for cargo shippers to handle increased cargo volumes, new kinds of cargoes, or new supply chains.

Our research results are consistent with those obtained by Nowy [28]. We too showed that deepening of the fairway contributes to increasing the navigation safety. The ships which hitherto were able to enter the port only upon obtaining individual permission from the harbour master, in appropriate weather conditions, will be able to enter the port without such restrictions. This will increase delivery timeliness and decrease the logistic costs. The cargo shippers who have their own terminals in the Szczecin port will be able to abandon the services provided in third-party terminals located in ports with better parameters, and will be better prepared to work in crisis situations (e.g., in case of restricting the terminal operation due to COVID-19).

Our research made important theoretical contributions in the field of maritime transport economics that the fairway deepening will have a positive effect on the foreland structure of the Szczecin port: the share of the distant (extra-European) foreland will increase at the expense of the close foreland. The anticipated change in the foreland structure brings with it opportunities and challenges for shippers, port operators, and the port authorities.

The semi-structured in-depth interviews with selected representatives of cargo shippers confirmed the relationships previously identified by the calculations.

According to the study findings, the fairway deepening results in favourable changes in relation to the cargo handled:

- Increase in transshipments of currently handled cargo;
- New cargo coming from the foreland that has not hitherto been served. The share of cargoes originating from/destined to the extra-European foreland will rise;
- New unitised cargoes, which have so far been shipped to the extra-European foreland via other southern Baltic seaports.

The increase in transshipments will result from the strengthening of currently served supply chains, changes in the foreland structure and the development of new supply chains, as well as the relocation of load weights from other competing ports. The relationships we investigated are shown in Figure 6. The recommendations indicated in the figure are described in more detail below.

The important practical findings of our study provide a set of recommendations that are worth developing further to take full advantage of the opportunities arising from the deepening of the fairway. For shippers to make decisions that increase their involvement in cargo shipment through the port of Szczecin, additional measures are needed, which include actions taken by port operators, port authorities, and ship operators. The most important of these are:

- Port operators:
    - More investments in the port handling equipment (increasing the equipment capacity) and storage facilities;
    - Developing existing terminals and new ones dedicated to specific cargo, e.g., liquid cargoes.
- Port authorities:
    - Upgrading the quays and port basins both in bulk and general cargo areas, adjusting them to the new depths of the fairway;
    - Creating a favourable climate for the development of long-term business and investment relations between stakeholders;
    - Creating conditions/incentives for the development of a network of feeder connections, including container ship connections;
    - Creating conditions/incentives for the development of container ship connections, handled by transoceanic operators, with a freight fee for feeder ship transport included in the overall rate for sea freight;
    - Intensification of marketing activities by the port authorities. Running promotional campaigns during trade events attended by shippers in order to publicise

the capability of the port to handle higher capacity vessels and the possibility for shippers to locate their own terminals on the port's grounds;
- Involvement and lobbying of port authorities on decisions taken by state authorities to improve land-based access to seaports and investments in road, rail, and inland waterways;
- Coordinating the activities of the various stakeholders.

- Ship operators:
  - Development of the network of feeder connections;
  - Establishing transoceanic connections.

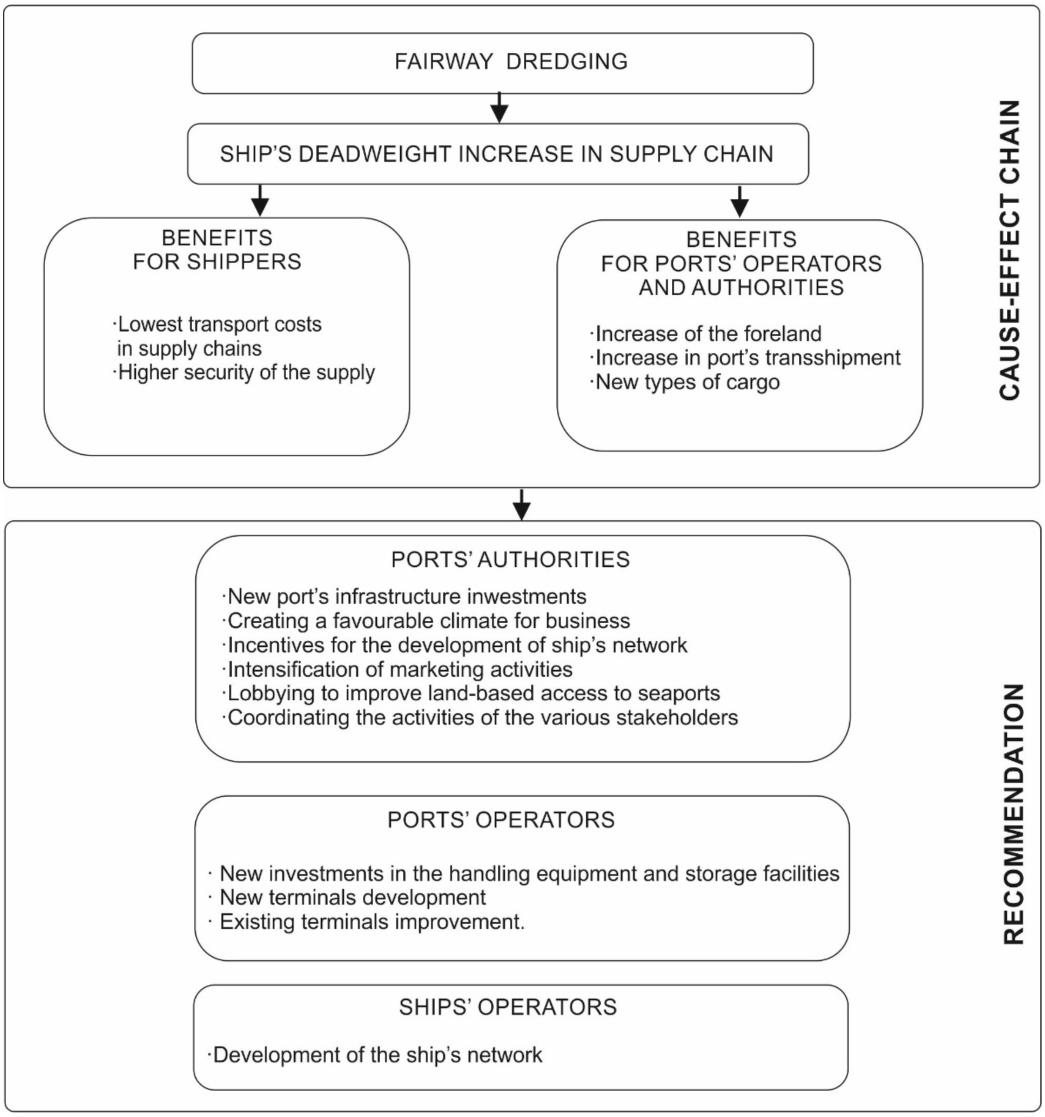

Figure 6. Cause-effect chain of fairway dredging and recommendation for stakeholders.

Naturally, the completed research study has its limitations. These are related to the freight dynamics observed on the markets worldwide. In order to mitigate the effects of the changes, the analysis was based on relative values, taking into account the percentage changes. Nevertheless, it is vital that transport costs be re-analysed prior to making any specific managerial decisions. The strength of the completed research is validation of the quantitative studies by means of qualitative studies.

Future research that we recommend is to examine similar dependencies that account for new infrastructure investments to improve the nautical accessibility, as well as their impact on shippers' decisions in other ports. In particular, it would be advisable to run studies related to ports in other parts of the world, which function in a different socio-economic environment, e.g., in Africa or South America, and also to account for specialised ports and terminals, e.g., those dedicated to container handling. Moreover, it would be worthwhile to conduct research studies to expand the perspective taken in this study (i.e., the one taken by cargo shippers) to include other stakeholders of the port-oriented supply chains, e.g., vessel owners.

6. Conclusions

Seaports operate in a constantly changing socio-economic environment, adapting to new technological trends, and responding to the challenges of climate change. Offering conditions that meet not only the current expectations of shippers but also the anticipated future trends is a necessity. One of the elements that will enable the shippers to operate effectively, efficiently, and economically is to provide nautical access infrastructure enabling smooth reception of vessels with sufficiently high deadweight. In the case of Szczecin, these are vessels from the Handymax segment. It is a necessary condition for further development of this port that will definitely increase its competitive potential in relation to the nearest ports.

This study aims at demonstrating the impact of fairway deepening on port-oriented supply chain costs and security of supply, as well as verification of the importance of these factors for cargo shippers' decision-making. Four research questions were answered in the course of the study. Both quantitative (Question 1 and 2) and qualitative (Validation of answers to Questions 1 and 2 as well as Questions 3 and 4) methods were used in the studies.

The quantitative part of our research confirmed that the investment in the seaport access infrastructure (i.e., the fairway deepening) brings benefits to cargo shippers. The cost of carrying one tonne of cargo over the whole transport chain is lower in the case of a Handymax bulk carrier compared with a Handysize vessel. The scale of expected benefits varies depending on the specifics of the port-oriented supply chain, i.e., the type of cargo and the distance covered. Our research showed that a 2.5-m increase in the permissible draught of ships results in a decrease of up to 25% in transport costs resulting mainly from the reduction in specific fuel consumption throughout the chain.

The ensuing results have a number of managerial implications, and they should be applied in the course of decision-making by entities engaged in configuration of port-oriented supply chains. The study applied the shippers' perspective, it proposes application of ships with bigger carrying capacities, and points to the related benefits. Not only shippers may benefit from improving the competitive position of the port as a result of better nautical accessibility, even though it is necessary to be well-prepared to be able to obtain satisfactory benefits. For port operators, bigger cargo volumes flowing into the port mean that they need to adjust the capacity of storage yards and to provide sufficiently efficient transshipment equipment. It is also necessary for port authorities to coordinate all the investments being implemented on the port grounds in connection with the fairway deepening, and to lobby for development of the access infrastructure to the seaport from the land side. All of that is needed to ensure that the outlays incurred to provide nautical accessibility will bring expected benefits.

To sum, our research study confirmed the hypothesis that the port investment being the deepening of the port fairway has a significant impact on decreasing the total costs of port-oriented supply chains and on improving the supply security. It is therefore a significant factor of the port competitiveness, which translates into an increase in transshipment volumes and has an impact on changing the structure of the port foreland.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14106255/s1.

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