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Seaports during the COVID-19 Pandemic: The Terminal Operators' Tactical Responses to Disruptions in Maritime Supply Chains

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Abstract: The world-wide crisis caused by the Coronavirus disease 2019 (COVID-19) pandemic had a significant impact on the global economy functioning and the sustainable development of supply chains. The changes also affected seaports being the key links of maritime supply chains. The purpose of the research study described in this article was to identify the sources and kinds of disruptions observed in various maritime supply chains as a result of the COVID-19 pandemic and their impact on the operations of various types of seaport terminals, namely those serving bulk (universal, specialised) and general cargoes (universal, specialised). An additional purpose was to identify the dependencies between the type of terminal and its main function, and the tactical decisions adopted by the particular terminals. The research was carried out using the multiple-case study method. The study covered some selected port terminals functioning in Polish seaports (Gdańsk, Szczecin, Świnoujście), applying direct, semi-structured in-depth interviews. The analysis of the results was carried out using the inductive reasoning method. The research study has shown that as a result of the COVID-19 pandemic some maritime supply chains ceased to exist, some of them were operating with decreased cargo volumes, while in other cases the transshipment volumes actually rose during the pandemic. Among terminal operators' tactical responses to disruptions in maritime supply chains, there were pro-active and adaptive measures. Pro-active (offensive) measures included actions taken by an enterprise in order to engage in new maritime supply chains, and even participating in establishing new maritime chains in response to limitations caused by the pandemic. Adaptive (defensive) measures covered actions taken by the port terminals as a consequence of changes in the existing maritime supply chains, caused by the pandemic in the port's foreland or hinterland. The research study results revealed that the terminals extent of engagement and tactical decisions related to the pandemic were depended on the type of terminal (universal or specialised) and its main function played within a supply chain.

Keywords: maritime supply chains; COVID-19 pandemic; seaports; terminal operators; distributions; response strategies; tactical decisions



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1. Introduction

The COVID-19 pandemic (Coronavirus disease 2019) caused a crisis in the global economy on an unprecedented scale and range [1]. It is estimated that the global economy and value chains will probably end up in an economic depression worse than the financial crisis of 2009 [2]. The restrictive lockdowns introduced in response to the pandemic led to drops in production, consumption, and employment [3]. Consequently, the changes resulted in disruptions in the functioning and the sustainable development of global

supply chains that influence the whole global economy, and thus also on the society and the environment [4–9]. The COVID-19 pandemic constitutes an immense challenge to transport and logistics operators [10], who had to quickly adapt their current operations to the new circumstances.

The research studies completed hitherto also indicate that the international mobility and global supply chains have contributed to the fast spreading of the pandemic [2,11]. The propagation of the pandemic was also facilitated by transport accessibility of certain geographical areas [12]. Thus, the pandemic reflects the growing range and effectiveness of the global transport system and the increased international mobility. Olapoju [13] pointed out that it was the passenger preference for a certain mode of transport that was decisive for spreading the virus in the particular era: the flu pandemic of 1918–1919 came via seaports, whereas COVID-19—via airports. However, this does not mean that the COVID-19 pandemic did not affect seaports. According to Notteboom and Haralambides [14], the impact of COVID-19 on the ports functioning is connected with evolution of ports as such towards logistics and industrial nodes in global supply chains. The port ecosystem is affected by a broad range of economic, social, institutional and environmental trends and shocks, and predominantly by a dynamic and highly unpredictable demand for port services. The factors increase the variability in international trade and cargo volumes in ports. Thus, the changes in supply chain functioning have a direct and indirect effects on seaports [15–17] being the key transport and logistics nodes of maritime supply chains (MSCs). Seaports, in particular port terminal operators, had to face the outcomes of the COVID-19 pandemic, taking up actions aimed at mitigating its negative effects on their operations [18]. Sudden and unexpected (in terms of scale and range of impact) disruptions observed in MSCs as a result of the COVID-19 pandemic required immediate tactical decisions. These decisions were challenging because of high level of uncertainty in the transport services market.

The studies done so far have not identified the sources and kinds of disruptions observed in various maritime supply chains as a result of the COVID-19 pandemic and their impact on the operations of various types of seaport terminals, namely those serving bulk (universal, specialised) and general (universal, specialised) cargoes. The purpose of the study described in this article was to fill this gap by:

1. Identifying the sources and kind of disruptions observed in various MSCs as a result of the COVID-19 pandemic and their impact on the operations of various kinds of port terminals, i.e., those handling bulk (universal, specialised) and general cargoes (universal, specialised).
2. Identifying the dependencies between the type of terminal and its main function, and tactical decisions adopted by terminals of various types.

The research was carried out using the multiple-case study method. The objects of the research study were various types of port terminals functioning in Polish seaports (Gdańsk, Szczecin, Świnoujście). The study applied qualitative research techniques—*in-depth analysis of the literature, and direct, in-depth, structured interviews*. The analysis of the results was carried out using the inductive reasoning method.

2. Literature Review

The conducted literature review is based on the analysis of the available latest studies (from the period of 2001–2021) selected mainly from The Web of Science (WoS) Core Collection and Scopus databases. While searching subject literature the following keywords were used, in particular: COVID-19 pandemic, transportation, supply chains, maritime supply chains, seaports, port resilience, port disruptions, terminal operators, response strategies.

The research studies completed hitherto have shown that the main risk connected with the COVID-19 pandemic in supply chains is distinctively characterised by long-term disruption existence, disruption propagations (i.e., the ripple effect), and high uncertainty [19–24]. The disruptions in global supply chains lead to significant uncertainties for the current functioning and future sustainable development of maritime sectors after the COVID-19 pandemic subsides [25,26]. In particular, the COVID-19 pandemic has demonstrated

the need to build more sustainable, smarter, and more resilient supply chains, because sustainability and resilience are complements [27–30].

The previous (pre-COVID-19 pandemic) studies addressing the issues of dependencies between seaports and supply chains in the circumstances of disruptions and uncertainties, pointed out the primary influence of port disruptions. Lam and Su [31] pointed out that the critical nature of a seaport is a connection point and a port disruption can cause cascading effects to the entire supply chain. In addition to the effect on port operations, a port disruption will be a strain on trade flows and the various supply chain stakeholders concerned. The earlier studies also indicated that the scale of maritime supply chain disruptions was mitigated by port resilience. Mansouri et al. [32], Kurapati et al. [33], and Wendler-Bosco and Nicholson [34] defined port resilience in the context of maritime supply chain disruptions as a function of the system's vulnerability and its capacity to recover to a sufficient level of service within an acceptable time frame after a disruption takes place. Similarly, Nair et al. [35] indicated that resilience accounted for both the innate reliability of a system and the ability of mitigating negative effects through quick recovery actions. Therefore, increasing global supply chain resilience is closely related to assessing port vulnerability [36–38].

The studies considering strategic management of terminal operators, focused on such disruptions as climate change, oil spill, security, social and political instability [31,39]. Similarly, Wendler-Bosco and Nicholson [34] showed that in MSCs, commonly identified sources of uncertainty were weather, ground transportation, and information sharing. The risks and uncertainties can cause port delays and port inoperability, consequently leading to maritime supply chain disruptions. However, some natural hazards are and can be continuously monitored [34,40]. Yip et al. [41] indicated that terminal operators were the groups of MSCs stakeholders that were the most important in promoting terminal efficiency at the global level, and that the operators with stevedore backgrounds showed a higher efficiency than carriers.

However, the COVID-19 pandemic has affected, in a way so far unexplored, the functioning of terminal operators, and the risk of a pandemic was not accounted for in their operations strategies. Nevertheless, maritime supply chain disruptions caused cascading effects to the seaports.

The studies completed so far on the effects of the COVID-19 pandemic on maritime supply chains and the activity of terminal operators mostly focused on maritime workers and the interface between sea staff and shore side personnel and seaport cities communities, and the team exchange in the conditions of various sanitary procedures and standards established by the authorities all over the world at the time of the pandemic [42–46]. The studies showed, *inter alia*, that sea staff in various identified seaport regions faced a disproportional level of exposure to the COVID-19 pandemic propagation, which was related to the proximity of urban and sub-urban settlements. Consequently, numerous restrictions and procedures related to handling the cargoes and staff were introduced to minimise the threat of further transmission of the disease.

To a lesser extent, studies addressed the impact of the COVID-19 pandemic on seaports operations as links of global supply chains.

Notteboom and Haralambides [14] analysed the impact of the pandemic on the general business activity of seaports. They found that during the first wave of the pandemic many ports all over the world had to cope with a moderate or considerable decrease in transshipment volumes and number of calls at ports, and a generally lower level of activity in logistics and industrial clusters (within ports and around them). Depellegrin et al. [47] indicated a negative impact of progressive lockdown restrictions connected with the COVID-19 pandemic on the ship traffic frequency and cargo handling at ports. Jeevan et al. [48] identified a negative impact of the COVID-19 pandemic which deepened the problems faced by seaports as a result of overlapping in the hinterland area. Van den Oord et al. [49] analysed the influence of the pandemic on the management of seaports as organizational networks. They indicated that as a result of the COVID-19 pandemic it was necessary to review the

way of managing the seaports (crisis management and network governance) in order to effectively cope with the problem such as the COVID-19 pandemic.

In terms of the kinds of cargoes handled at ports, the prevailing part of the research focused on the effects of the COVID-19 pandemic on the operations of container terminals.

Russell et al. [50] found that the supply chains which included container ports were characterised by increased uncertainty resulting from a number of factors (such as socio-economic factors) and supply chain strategies that were changing in response to the market dynamics. The authors indicated that the COVID-19 pandemic intensified this phenomenon.

Donnan et al. [51] based on the case study of Port of Virginia (United States) described the most and least disruptive scenarios of emergent and future conditions, including hybrid scenarios involving the COVID-19 pandemic. A methodology was developed for any port to address its emergent and future conditions via its strategic plans.

Notteboom et al. [52] analysed in detail, in terms of time and space, the sequences of supply and demand shocks caused by COVID-19 in container ports and in container shipping, comparing the events to the financial crisis of 2008–2009. It was observed that even though on the aggregate level the financial crisis and the COVID-19 pandemic seemed to have brought similar effects, the effects did not display similar patterns in ports and shipping networks. In the case of the COVID-19 pandemic, the effects are a result of the way the ports and the shipping industry operate as part of complex supply chains and the structure of handled cargoes. Each sudden drop in consumer demand immediately affects the level of shipping and port operations, and may lead to changing the corporate strategies or even market structures. The authors also pointed to resilience of the demand for basic goods, especially foods and medical products. Moreover, they found that in the 1st half of 2020 the COVID-19 pandemic affected the handled transshipment volumes in container ports, but had no significant effect on the margins earnings before interest, taxes, depreciation and amortization (EBITDA).

Notteboom et al. [52] simultaneously showed that most container terminals in the circumstances of lower/non-existing demand and suspended business activity displayed considerable adaptive capabilities (they searched for new customers, ships and cargoes) and started to introduce rationalization strategies (intensified cost control), and also reorganization of their operations (observance of sanitary protocols and other requirements such as social distancing, port worker shift schemes, etc.). They underlined that automation and digitization of services played a key role in the organizational changes. Due to that, the impact of COVID-19 on container ports was shorter and on a smaller scale than it had initially been expected. This made it possible to continue the business activity and increase the resilience of MSCs, even in the peak of the crisis in April and May 2020.

The studies completed so far also suggested a number of measures and actions that should be taken in order to counteract adverse impacts of the pandemic on ports and the shipping industry. Such measures and actions may help the supply chains in mitigating any negative effects of the pandemic on their functioning.

Gaskin et al. [53], Faqiang and Abliakimova [54] and Kolesnikova [55] noticed that it was necessary to develop more effective national and international policies, in particular in order to meet the “safe port” requirements. To that end, cooperation was necessary between policy makers and officials in transportation and public health to promulgate policies and procedures to protect travellers and transportation workers from COVID-19. The studies suggest the need to ensure a universal approach to establish protocols and best practices to counteract the spreading of COVID-19, and to introduce strict financial sanctions in case of infringing the established principles. Jeevan et al. [48] also concluded that seaport policy and management during the COVID-19 pandemic and afterwards should take into account improvement of the hinterland transport infrastructure, especially rail transport. Zhang et al. [56] in addition to strengthening the overseas port policy, also pointed to measures such as port linking tracking, avoiding ship charter disputes and legal risks, improving the system of prevention and control of cruise ships, and promoting the development of smart ports and smart shipping. Also Chinonyerem et al. [57] and

Doumbia-Henry [58] underlined that seaports response strategies had to a larger extent take into account a stronger integration of global supply chains. It is necessary to further standardise the procedures and digitise the ports in order to streamline transmission of information required by authorities in connection with formalities related to cargoes, and to facilitate and decrease administrative burdens for ship data providers [59].

Russell et al. [50] referring to the activity of container ports indicated that ensuring flexibility in port logistics was more important than ever, so as to be able to cope with uncertainty, now and after the COVID-19 pandemic.

At the same time, the studies underline the need to structurize information to support decision-making process for organization of transport of selected cargo groups during the COVID-19 crisis [60]. It should be also noted that available literature includes studies showing managers respond strategies, managerial insights and recommendations facilitating decision-making process related to supply chains management [16,61], however, these studies do not investigate decisions made in COVID-19 pandemic conditions.

The impact of the COVID-19 pandemic on port transshipment in relation to cargo groups other than containers was studied by Zhang et al. [56]. They assessed the effects of the pandemic in the Chinese ports in the first quarter of 2020. Their findings showed that the COVID-19 had been transmitted to the shipping industry by global supply chains. There is a strong Granger causal relationship between the COVID-19 daily new cases and the Baltic Dry Index. They found that the pandemic within a short time had the greatest impact on dry bulk cargoes, containers and liquid bulk cargoes. At that point it was forecast that the economy revival would be a slow process, and the COVID-19 epidemic would still have a long-term negative effect on the ports and the shipping industry.

The studies completed so far also point to various natures of disruptions taking place in various MSCs (various industries) in the course of the COVID-19 pandemic.

Michail and Melas [62] studied the changes in the freight rates for dry bulk cargoes as well as clean and dirty tankers in response to the COVID-19 pandemic. The research results suggested that such events had a direct effect on the dry bulk cargo and dirty liquid cargo segments. It was underlined that there were also second-round effects, mainly due to a drop in oil prices, and in some cases third-round effects as a result of stock exchange impacts. It was pointed out that the demand in the economy had a significant impact on both dry bulk carriers and clean tankers, whereas oil-carrying vessels did not register this sort of relation. Loske [63] analysed the volume and freight capacity dynamics in German food retail logistics. According to the study, the increasing freight volume for dry products in retail logistics did not depend on the duration of the COVID-19 epidemic, but on the strength quantified through the total number of new infections per day. Coluccia et al. [64] noticed that fresh and perishable goods produced or harvested during the first wave of the COVID-19 pandemic were affected by changes in prices, whereas the products that could be stored for longer did not suffer any significant effects. Gray [65], in turn, observed new demands for transportation services, which could impact Canadian agricultural supply chains. The analysis has shown that access of agriculture to mass maritime transport, rail transport and road transport generally improved during the pandemic, which was enhanced by the decreased demand for the transport services from other sectors of the economy. The analysis also covered the impact of the pandemic on the functioning of the shipping lines carrying perishable goods, and the measures taken by them in response to the disruptions in food supply chains [66]. Verma et al. [67] noted that the global consumption of oil-derived fuels was limited due to the total or partial lockdown in most countries in connection with the pandemic.

However, the studies done so far have not provided a full answer to the question: to what extent the type of port terminals (universal/specialised/specialisation type), type of prevailing function (transshipment /storage) and kind of maritime supply chain (sector of the economy) determine the character and scope of the impact of the COVID-19 pandemic on port terminals operations and response tactical decisions of the terminals operators (Table 1). The purpose of the research described in this article was to fill the gap. The

preliminary research regarding the condition of selected port companies functioning in the seaports of Poland and Ukraine were conducted by Pluciński et al. [68].

Table 1. Comparison of the contributions of the previous studies.

Author(s)	Type of the Terminal Analysed				Identification the Influence on			Response Strategies		Tactical Decisions	
	Specialised	Universal	Not specified	Cargo turnover	Shipping	Hinterland	Management strategies	International procedures to protect travellers and port staff	Stronger integration of global supply chains	Identification of the types of tactical decision	Identification the dependencies between the type of the terminal and tactical decisions
Notteboom and Haralambides [14]	✓	✓	✓	✓							
Depellegrin et al. [47]			✓	✓	✓						
Jeevan et al. [48]			✓		✓						
Russell et al. [50]	✓						✓				
Donnan et al. [51]			✓				✓				
Notteboom et al. [52]	✓			✓			✓				
Zhang et al. [56].	✓	✓		✓	✓						
Michail and Melas [61]					✓						
Gaskin et al. [53]			✓					✓			
Faqiang and Abliakimova [54]			✓					✓			
Kolesnikova [55]			✓					✓			
Chinonyerem et al. [57]			✓						✓		
Doumbia-Henry [58]			✓						✓		
Presented paper	✓	✓		✓		✓	✓			✓	✓

3. Research Methodology

The multi-case-study method [69,70] was applied for the purposes of this paper. This research approach enables us direct observations and interactions that provide insights that are not possible from a distance. In the first stage of the research study, a literature review was carried out, which highlighted an existing research gap.

In the second stage, the research method and the main object of the research were selected. The main research techniques used in the data collection and analysis were qualitative research techniques (Figure 1).

After the literature review presented in Section 2, the following research questions were formulated:

1. What was the impact of MSCs disruptions on the operations of various port terminals?
2. Is there a dependency between the type of terminal and its function, and the tactical decisions taken by the terminal administrators during the COVID-19 pandemic?

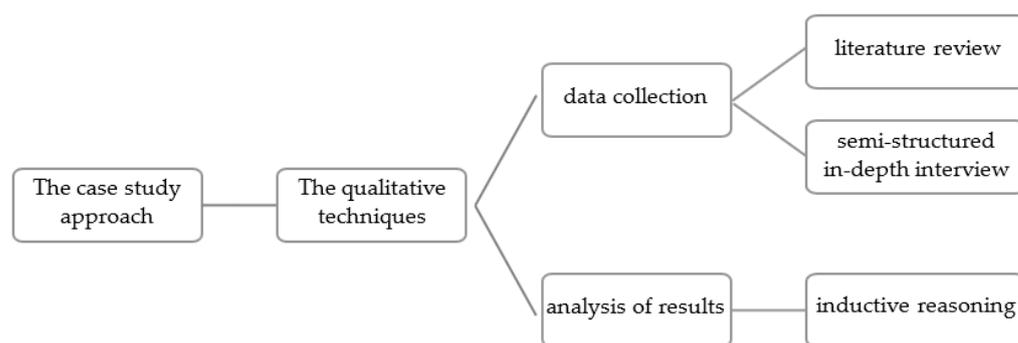


Figure 1. The case study research design.

In order to obtain answers to the posed research questions, semi-structured in-depth interviews (IDI) [71] were carried out. According to Kvale [72] our IDI included the following stages: thematising, designing, interviewing, transcribing, analysing, verifying, and reporting.

The first step in conducting the semi-structured IDI was to identify the entities. The object of the study was the terminal operators. The study adopted a definition of terminal operator as an enterprise operating within the territory of a seaport or several seaports (in one or several port areas), providing various port services, including in particular transshipment and storage. The selection of the entities to be covered by the study was based on a diverse profile of activity and being part of diverse maritime supply chains. The studied entities also showed various potentials, having from several to one thousand employees. The characteristics of the entities covered by the study are presented in Table 2. One of the analysed terminal operators has terminals in two different seaports.

Table 2. Characteristics of selected terminal operators.

Scope of Activity of Terminal Operator	Number of Terminals	Maritime Supply Chains (Cargo Type)	Flow Directions	Location	Prevailing Services/Supplementary Services
Terminal Operator A Universal: dry bulk cargoes and conventional general cargoes	3	iron ores, coke, steel products, cellulose, fertilisers	Export, import	Port of Szczecin	Transshipment/Storage
Terminal Operator B Specialised: liquid bulk cargoes	2	liquid fuels, liquid chemical cargoes	Import	Port of Szczecin Port of Świnoujście	Storage/Transshipment
Terminal Operator C Specialised: dry bulk cargoes	2	grain, soybean meal	Export, import	Port of Szczecin	Transshipment
Terminal Operator D Universal: conventional general cargoes	1	steel products, wood	Export, import	Port of Szczecin	Transshipment/Storage
Terminal Operator E Specialised: Unitised general cargoes	1	containerised general cargoes	Export, import	Port of Gdańsk	Transshipment
Terminal Operator F Specialised: General cargoes	1	frozen fish	Import	Port of Gdańsk	Storage

Interviews were held with 6 representatives of terminal operators running their business activity in the Polish seaports in Szczecin, Świnoujście and Gdańsk (Figure 2). The interviews were conducted in the form of direct personal or on-line meetings (using the MS Teams application). The terminal operators were represented by the management: Board Presidents, Board Vice-Presidents, Board Members or Operations Managers.

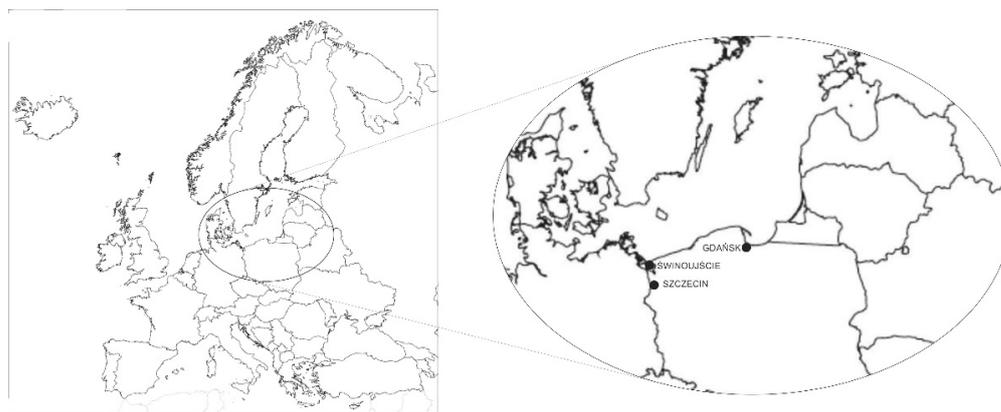


Figure 2. Location of analyzed Polish seaports.

The interviews were held twice, in the two periods following the subsequent phases of the COVID-19 pandemic:

- For the 1st phase (March, April, May, June 2020)—in the period: 8–23 August 2020.
- For the 2nd phase (July, August, September 2020)—in the period: 7–14 October 2020.

The terminal(s) operators were asked the following questions:

1. Did the port terminals during the COVID-19 pandemic observe any significant changes/disruptions in transshipment and storage operations, and if so, what were they like?
2. What was the source of those changes/disruptions?
3. Is it possible to distinguish various phases of the impact (within the studied periods)?
4. What decisions were taken by the port terminals operators in response to those changes/disruptions?
5. What effects did the decisions bring for the operation of the terminals?

The research results are presented in a descriptive and tabulated form. In the analysis of the research results, one of the reasoning methods was applied, namely inductive reasoning, defined as a process that begins with premises about objects that have been examined into conclusions about objects that have not been examined [73]. The objects were assumed to be the 6 interviewed terminal operators. Considering the fact that in inductive reasoning the matter of key importance is a diversity effect (a novel property is more likely to be generalised when it is shared by an evidence sample composed of diverse instances) [74], the analysis covered 14 different transport chains of which the studied terminals were part, in terms of both loading and unloading operations. To identify the conclusions, apart from the analysed specific supply chains, the study also applied the authors' knowledge and experience gained as a result of participating in numerous studies (strategies and development programmes) ordered by governmental authorities, port authorities and terminal operators operating in Polish seaports.

The results are presented in the form of a diagram showing the type of terminal and its main function, and the tactical decisions made by the terminal operators. In the Discussion, the obtained results are confronted with the latest literature.

4. Results

4.1. Identification of Disruptions and Changes in MSCs as a Result of the COVID-19 Pandemic from the Perspectives of Various Terminals Operators

4.1.1. Terminal Operator A: Bulk Cargo and General Cargo Supply Chains

Operator A operates three terminals (bulk cargo, coal and general cargo). In the 1st phase of the study, they saw a negative impact of the COVID-19 pandemic on the terminals operation, particularly with respect to supply chains providing raw materials and products for the steel industry. The prevailing type of service is cargo transshipment.

The first analysed example of MSCs was the import chain of iron ore from the African and South American foreland to the Szczecin port's domestic hinterland (Kraków). The pandemic accelerated making a decision by a big steel company to abandon part of operations in the ironworks (closing down the blast furnace and the steel mill, retaining the rolling mill activity). The decision was additionally justified by growing costs of CO₂ emissions and increasingly tough competition with steel producers from outside the European Union. For Terminal Operator A, the decision of the steel company meant a loss of ca. 100 k tonnes of regular cargoes per year.

Another example of a supply chain whose part was Operator A was a coke export chain from the Polish hinterland of the Szczecin port to the South European markets. The reason for the chain disruption was the temporary close-down of automotive production facilities in Southern Europe (Spain). This contributed to limiting the metallurgical production in Spain and resulted in the temporary withholding of coke exports to that country. The coke plant was forced to store the sold but unsent cargoes and soon ran out of storage space. This is confirmed by data on coal exports (in statistics coke is shown as coal) (1Q 2020—337 k tonnes; 2Q 2020—60 k tonnes). A solution to this problem was the possibility of using long-term storage yards in ports (which would mean extending the standard storage periods twice or even three times). This made it possible to survive the difficult period and to retain the chain durability. At the end of 2020, coke exports rose enough for the annual results to exceed the 2019 transshipment volume by 100 k tonnes. Such a significant increase over a short time required Operator A to make decisions and take intensive actions connected with rail and ship transport of coke.

Moreover, Terminal Operator A made an effort to increase the volume of handled cargoes that enjoyed a considerable demand at the time of the pandemic. An example could be the imported cellulose which during the COVID-19 pandemic was also brought from new markets (new ports of the European foreland, South American ports). However, an increase in transshipments in this group did not compensate the drops in the whole conventional general cargo group in 2020 (compared to the previous years). This was an effect of, first and foremost, the drop in transshipment of steel products exported from Poland. The decrease was not compensated even by a new supply chain of steel products imported to the Polish hinterland (pipes). The operator also took up actions connected with more effective competing with other port operators. The outcome of those actions was engagement of Operator A in handling the fertiliser (urea) supply chain, which was imported from the Asian foreland to the hinterland of the Central European countries. However, it should be noted that the effects of most actions focused on winning new cargoes could be felt no earlier than at the end of the 3rd quarter and in the 4th quarter of 2020.

The pandemic also brought considerable uncertainties connected with transshipment of key cargoes to be handled by Terminal Operator A in the future. This was due to the lack of unambiguous declarations from the shippers with regard to the volumes of coal, ores, steel products which were to be handled by the port.

In the course of the second phase of the study (beginning of Q4 2020), the terminal operator still felt the negative impact of the pandemic, and there were still lower volumes of transshipments compared to the previous year (by ca. 15%). Nevertheless, due to their diversity, the transshipments in the "other bulk" group were close to the previous year's level. Good forecasts regarding future transshipments also regarded coke.

4.1.2. Terminal Operator B: Liquid Fuel and Liquid Chemicals Supply Chains

Operator B has two terminals (in Szczecin and in Świnoujście) that handle liquid fuels and liquid chemicals. Most revenues came from cargo storage operations. The interviewed operator stated that they did not experience any negative consequences of the pandemic (1st phase of the study). An exception was the necessity to take standard actions aimed at protecting the human resources in the course of the pandemic (just like in the case of any other business entities).

The stability of the operator's functioning during the pandemic (1st phase of the study) results from the specific nature of the activities at the terminals managed by them. They sell storage space (most often for one year in advance), whereas transshipments stand for only a small portion (ca. 10%) of their revenues.

In the 1st phase of the pandemic, fuel importers changed their operation strategy. In the past, they would fill the leased tanks on a regular basis. In the 1st phase of the pandemic, fuel importers took advantage of low purchase prices and filled the tanks up as early as in March 2020.

In the studied period, one of the customers of the operator ceased ordering transshipment of diesel oil at the deepwater terminal (Świnoujście) from large vessels to smaller ones that could enter the port in Szczecin (the customer's location). This was related to the change in the policy of Russian exporters of diesel oil. Before the COVID-19 pandemic, the Russian exporters did not want to load the cargoes onto smaller vessels. After the outbreak of the pandemic, when the demand for fuels dropped, they started to show more flexibility in that regard.

At the deepwater terminal, the cargoes that used to be transported from Świnoujście to Szczecin (ca. 70 km) were replaced by the customer with cargoes that could be stored for longer. Thus, the customer leasing the storage space at the terminal in Świnoujście was able to take advantage of the contango situation.

The pandemic also had an impact on postponing (to the time after the pandemic) the date of commissioning of a new investment that the operator had been preparing in cooperation with the external partner.

In the course of the 2nd phase of the research (2nd phase of the pandemic) the operator still did not see any negative consequences of COVID-19 on the functioning of the terminals in 2020. However, the terminals operator was concerned about the possible impact of the persisting pandemic on their operations in 2021, namely on the future volumes of fuel sales (teleworking and tele-education resulted in decreased demand for car fuel). In case of a ca. 15% drop in fuel consumption in 2020 (compared to 2019), the mandatory reserves would be reduced by the same percentage in 2021 (they depend on the imports volumes in the previous year).

In September 2020, the terminal operator returned to the supply chain structure from before the pandemic, i.e., a large vessel with diesel oil from Russia—terminal in Świnoujście—storage—transport on smaller vessels to Szczecin. This was also due to the decreased contango profit for the customer.

4.1.3. Terminal Operator C: Grain Supply Chain

Operator C runs their operations in the port of Szczecin at two affiliated grain transshipment (export and import) terminals. The prevailing service offered by the operator is transshipment.

In the 1st phase of the COVID-19 pandemic, a 30% drop in imported soybean meal transshipment was observed. The drop was caused by a slower rate of transshipment operations in the seaports of Argentina as a result of introducing organisational changes aimed at protecting the stevedores' health in the course of the pandemic. In that case, the supply chain had been distinctly altered. Before the pandemic, maritime deliveries were made on a monthly basis as follows: port of loading in Argentina (a 40 k DWT vessel)—port in Gdynia (unloading of 20 k tonne cargo)—port of Szczecin (unloading of the remaining 20 k tonnes). In the course of the pandemic, a change in the configuration of the intermediate ports and the single consignment size were changed: port of loading in Argentina (a Panamax ship)—unloading of the whole cargo in the port of Rotterdam (registered seat of the cereal holding)—loading a 5 k tonne cargo in Rotterdam onto a coaster ship—unloading the whole cargo in the port of Szczecin. As a result, the deliveries were made more frequently, but the general cargo volume decreased by ca. 30%.

From the point of view of the corporate group (Operator C), the owner of the terminals included in the study, the decreased transshipments of imported cargoes were compensated

by an increase in exports of grain via the port in Szczecin to African markets (at the beginning of the pandemic there was a rise of ca. 30% compared to analogous periods in previous years). However, it should be noted that the increase was independent from the COVID-19 pandemic and was connected with the perturbations on the global grain market.

In the case of the import terminal, the drop in transshipment and the temporary reconfiguration of the route of the maritime part of the transport chain did not put on hold the investment project implemented by the operator. The project consisted in investments in port handling equipment connected with warehouse logistics. The implementation of the investment project will contribute to shortening the cargo handling time at the import terminal.

In the course of the 2nd phase of the research (2nd phase of the pandemic) it was found that transshipment volumes of exported grain and imported soybean meal came back to the levels of analogous periods in previous years.

4.1.4. Terminal Operator D: Conventional General Cargo Supply Chain

Terminal Operator D, who manages the universal general cargo terminal, was affected by negative consequences of the COVID-19 pandemic. The operator's activity focuses mainly on transshipment.

In the 1st phase of study it was established that first and foremost there was a drop in transshipment of steel products imported from the European foreland of the Szczecin port. The products recipients were car production facilities located in the hinterland of the Szczecin port. Thanks to the proactive measures taken by the operator, the drop was compensated by transshipments of exported wood (which before that had never been handled at the terminal) that couldn't be sold on the domestic market. In the 1st phase of the pandemic, furniture production facilities in Poland were closed. The situation of wood sellers was further deteriorated by the oversupply of wood being the result of drought and damages caused by pest. The shippers of the wood found recipients in the foreland of the Szczecin port (paper mills in Scandinavia). Consequently, the maritime trade handled a cargo that before the pandemic had only been sold on the domestic market.

In the 2nd phase, the trade volumes of the imported steel were close to the level before the pandemic. The volumes of exported wood were no longer as high as in the period when furniture production plants were closed in Poland, but Operator D still handled them. This was due to the persisting oversupply of wood in Poland and East Germany.

4.1.5. Terminal Operator E: Unitised General Cargo Supply Chain

Operator E operates the deepwater container terminal and focuses on transshipment activities.

During the 1st phase of the research, they noted a distinct drop in transshipments of imported cargoes, which before the COVID-19 pandemic accounted for the dominating part of the terminal's activity. The terminal serves oceanic container ship connections with Asian ports, and 60% of the imported cargoes come from China. The pandemic development in China contributed to temporary freezing of a significant part of Chinese production capacities, and in consequence a drop in export volumes. The exported goods transshipment volume at the terminal remained on a level similar to the one from before the pandemic. Consequently, the share of exports in the total turnover of the terminal increased. The stabilisation of the exports volume was an effect of the significant decrease in inventory in China. In China, there was an increase in demand for imported goods from European markets where production was still running (i.a. from Belarus). That situation led to a considerable (five-fold) increase in rates for oceanic freight of containers from the terminal to Asia.

Moreover, in the 1st phase of the study, the handling of imported containers took 1–2 days more than usual. This was connected with the health and safety concerns voiced by customs officers performing the customs clearance. At the beginning of the 1st phase of the pandemic (March 2020), an increased demand for container storage and stripping was observed at the terminal. In the hinterland transport, there were problems with timely

handling of road vehicles (queues at border crossings). That led to increased engagement of rail transport, as trains did not encounter any problems at border crossings. Additionally, rail haulage started to be very punctual due to the decreased passenger traffic using the same infrastructure. In effect, the share of rail haulage in transporting containers to/from the terminal's hinterland rose from 33 to 35%. The pandemic forced the terminal to suspend cooperation with third-party service providers (e.g., crane services).

During the 2nd phase of the research, the transshipment volume was back to the level in the analogous period of 2019, still, there was no rising trend that was observed in the previous years. The level of imports from China was influenced by the economic growth in that country, amounting to 9.5% between Q2 and Q3 2020. Exports (to Asia and North America) were positively affected by the depreciation of the Polish currency in that period.

4.1.6. Terminal Operator F: Frozen Cargo Supply Chain

Terminal Operator F operates a specialised terminal for frozen cargoes, which also offers cargo storage services to customers.

During the 1st phase of the study it was found that the analysed terminal did not experience a negative effect of the COVID-19 pandemic. An exception was the extended time of ship handling at the beginning of the 1st phase, due to the implemented sanitary procedures (e.g., checking the staff's temperatures) and changes in the organisation of the terminal's operation. However, this did not have a negative effect on the handled supply chains due to the long storage times of cargoes at terminals of this kind. At the beginning of the 1st phase of the pandemic, the cargoes were stored for shorter times, as requested by some of the terminal's customers. This was the consequence of the increased demand for canned fish products in the hinterland (people making stocks of canned food in case of quarantine).

During the 2nd phase of the study it was found that the terminal still did not experience any major changes in its operations. The operator handles very stable volumes of fish (no possibility of a significant increase in demand due to the limited resources). The handled cargoes meet the basic consumer needs. At that time, the ship handling time was back to normal as before the pandemic (the effect of experience gained, and refining of the procedures applied by the inspection services).

Table 3 presents the described changes in the operation of various types of port terminals in the context of disruptions identified in supply chains.

Table 3. Sources, causes and effects of the COVID-19 pandemic on the operations of the studied port terminals.

Terminal Operator	Maritime Supply Chain	Source of MSC Disruption	Cause of MSC Disruption	Effect on Prevailing Activity of the Terminal	Anticipated Impact on Activity of the Terminal	Significant Changes in Port handling/Hinterland Transport
A	1. Imports of iron ore from Africa and Brazil to the Polish hinterland of the port	Domestic hinterland of the port	Significant limitation of metallurgical production level in Poland	↓ transshipments		
	2. Export of metal products from the Polish hinterland to i.a. Great Britain	Domestic hinterland of the port	Decreased competitiveness, and consequently considerable limitation of metallurgical production in Poland	↓ transshipments		
	3. Export of coke from Polish hinterland to smelting plants in Spain	The port's foreland	Significant limitation of metallurgical production in Southern Europe	↓ ↑ transshipments-storage time	short-term ↓ long-term	Disruptions in road vehicles handling (delays at the border crossing)

Table 3. Cont.

	4. Import of cellulose from new sources—Sweden, Chile—to Polish hinterland	Domestic hinterland of the port	Increased demand for cellulose products in Polish hinterland	↗ transshipments		
	5. Import of steel semi-finished products (pipes) from Spain, Italy, Russia to Polish hinterland	Domestic hinterland of the port	Increased demand in connection with investments in gas pipelines in Polish hinterland	↗ transshipments		
	6. Import of fertilisers (urea) from Iran to hinterland of Poland, Germany, Czech Republic, Austria	-	Cargo taken over from competitors	↗ transshipments		
B	1. Import of liquid fuels from Russia to Polish hinterland	Domestic hinterland of the port	Decreased demand for fuel, a drop in fuel prices	↘ transshipments storage time	— — — short-term long-term	Temporary switch-over from using two ships (including transshipment in Świnoujście) to direct transport with a smaller ship
C	1. Import of soybean meal from Argentina to Polish hinterland	The port's foreland	Disruptions in ship handling in Argentinian ports	↘ transshipments	— — —	Temporary decrease in ship size (from handymax to coaster)
	2. Export of grain from Polish hinterland to Africa (Morocco, Egypt)	-	-	↗ transshipments	short-term long-term	
D	1. Import of smelter products from Holland to Polish hinterland	Domestic hinterland of the port	Withholding the car production	↘ transshipments	short-	
	2. Export of wood from hinterland of Poland and Eastern Germany to paper mills in Sweden	Hinterland of the port	Withholding furniture production and drought (oversupply of resources)	↗ transshipments	term — long-term	
E	1. Import of containerised cargo from China and South Korea to hinterland of Poland and other Central European countries	The port's foreland	Withholding the industrial production in China	↘ transshipments	short- term — long-term	Increased number of container stripping operations Disruptions in road vehicles handling (delays at the border crossing) Increased share of rail
	2. Export of containerised cargoes from hinterland of Poland and other Central European countries to China	The port's foreland	increased demand for FMCG in China (due to production withholding) imported from Europe (i.a. from Belarus)	↗ transshipments		
F	1. Import of frozen fish from Iceland and Norway to Polish hinterland	Hinterland of the port	Increased demand for canned food in 1st phase of pandemic	↘ transshipments storage time	— — — short- term — long-term	

Key: ↗ increase. ↘ decrease. — no change.

4.2. Terminals Operators' Response to COVID-19 Pandemic—Tactical Decisions

The analysis of the measures taken by the terminal operators shows considerably diversified engagement of the individual terminals in preventing/counteracting the COVID-19 pandemic. The measures may be classified as (Table 4):

1. Pro-active (offensive) measures—actions taken by an enterprise in order to engage in new maritime supply chains, and even participating in establishing new maritime chains in response to limitations caused by the pandemic, and
2. Adaptive (defensive) measures—actions taken by the port terminals as a consequence of changes in the existing maritime supply chains, caused by the pandemic in the port's foreland or hinterland.

Table 4. Supply chains analysis and tactical decisions of the terminal operators.

Terminal Operator	Main Function	Type of Terminal	Maritime Supply Chain	Action on the Supply Chain	Tactical Decisions
A	transshipment	universal—with the domination of bulk cargo	1	discontinuation of the supply chain	pro-active—change of supply chains (searching for new supply chains)
			2	reduction of transshipment volume	
			3	reduction of transshipment volume	
			4	creation of a new supply chain	
			5	creation of a new supply chain	
			6	creation of a new supply chain	
B	storage	specialised—bulk cargo terminal	1	extension of storage time	adaptive—change of storage time (changing the organisation of the terminal's work, adjusting the terminal's service offer)
C	transshipment	specialised—bulk cargo terminal	1	reduction of transshipment volume	adaptive—change of flow directions (no possibility of taking actions to mitigate the phenomenon)
			2	increase of transshipment volume	
D	transshipment	universal—with the domination of general cargo	1	reduction of transshipment volume	pro-active—change of supply chains (searching for new supply chains)
			2	creation of a new supply chain	
E	transshipment	specialised—general cargo terminal	1	reduction of transshipment volume	adaptive—change of flow directions (no possibility of taking actions to mitigate the phenomenon)
			2	increase of transshipment volume	
F	storage	specialised—general cargo terminal	1	reduction of storage time	adaptive—change of storage time (changing the organisation of the terminal's work, adjusting the terminal's service offer)

Our research study has shown that the extent of engagement and the way of coping with the pandemic depended on the type of terminal (universal or specialised) and on the main function played by them in a supply chain.

4.2.1. Pro-Active measures—Change of Maritime Supply Chains

The highest level of pro-activity was shown by two universal terminals where the dominating function was cargo transshipment (Terminal Operators A and D). These ter-

minals were the ones which were the most affected, because as a result of the pandemic some of the supply chains served by them ceased to exist, definitely or temporarily. In the case of Terminal A, ceased transshipments of iron ores or the considerable reduction of exported steel products transshipments were a stimulus for the operator to engage in new chains of imported steel pipes, urea or cellulose imported from new places of origin. The remedial measures taken by the operator were supplemented with a strategy of developing the storage function (coke). However, the revenues from longer-term storage of coke did not compensate the reduced income connected with the drop in transshipments (main source of revenue). Nevertheless, finally it turned out that the measures taken made it possible to retain the maritime supply chain of coke and to reach high annual volumes.

A similar situation took place in the case of Terminal Operator D who as well pursued the strategy of engaging into newly created maritime supply chains, which proved to be a success. The decrease in transshipments of steel products imported to Poland was fully compensated by high volumes of wood exported from Poland to Sweden.

In both cases, prevention of adverse effects of the COVID-19 pandemic required active search for new opportunities for the terminal and adapting the service offer (a different technology of cargo transshipment and storage). That was possible due to the broad range of transshipment and storage offer, adequately trained staff, universal equipment and a number of storage yards and warehouses which were able to handle various cargoes.

4.2.2. Adaptive Measures—Change of Storage Period

Specialised terminals whose main function was cargo storage made decisions that helped them adapt to the changes the pandemic brought in the port's hinterland or foreland (Terminal Operators B and F). The COVID-19 pandemic also led to other needs related to storage. In the case of Terminal Operator B (fuels), the low prices of fuels inclined most importers to make purchases of fuels that were then stored in tanks leased at the terminal as early as at the beginning of the pandemic, and that led to extending the storage periods.

An attractive group of stored cargoes is fuel classified as the so called mandatory reserves. However, it is possible to expect that the prolonged period of the pandemic will lead to reduction of mandatory reserves levels in 2021 and this will force the terminal operator to take more pro-active measure in order to find new cargoes.

A change in storage time was also observed in the 1st phase of the pandemic at the specialised frozen cargo terminal (F). In this case the storage time was shortened, which was due to the faster turnover of frozen fish as a result of increased demand for canned fish products. The terminal was flexible enough to adapt to the new needs of the customers.

Both of the aforementioned terminals reacted positively to the new needs of their customers. In the case of the fuel terminal, this required intensification, within a short period, of transshipment operations which under normal circumstances would have been spread across the whole year. As for the frozen cargo terminal, in order to respond to the customer's new needs it was necessary to adapt the terminal logistics to the faster cargo turnover.

4.2.3. Adaptive Measures—Change of Flow Directions

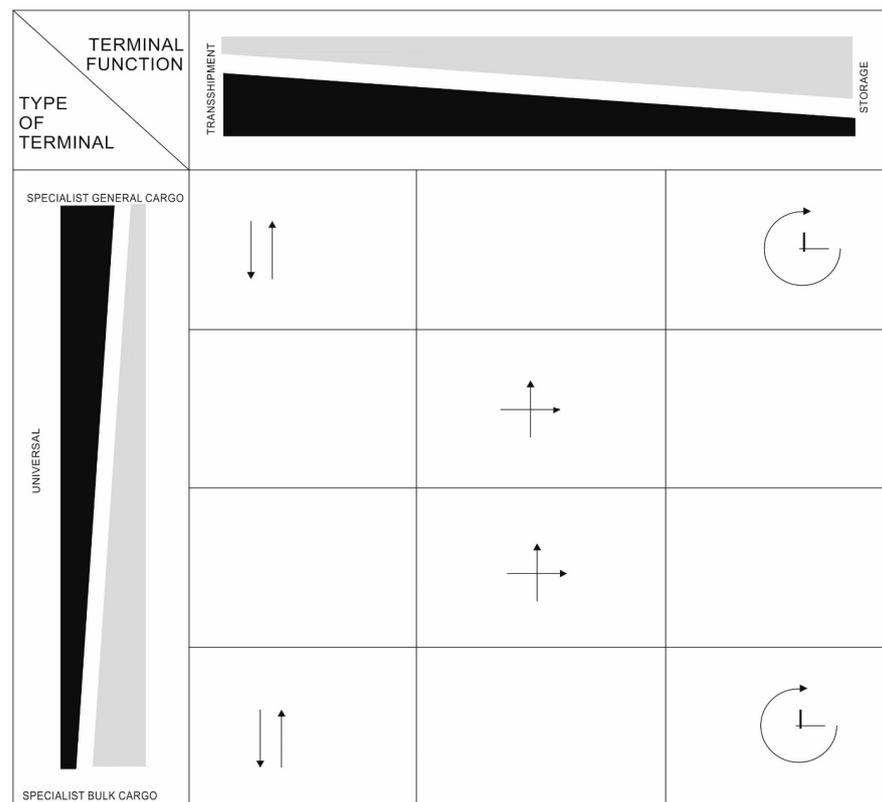
In the case of the specialised terminals focused on transshipment, the changes resulting from the pandemic mainly led to changes in the directions of cargo flows (Terminal Operators C and E). This cannot be called intentional decisions, it is rather an effect of changes taking place on the major markets served by the terminals. In the case of Terminal Operator C, the drop in transshipments of imported soybean meal (import terminal) were compensated with increased transshipments of grain, mainly wheat (export terminal). However, it should be noted that in order to mitigate the adverse effects of decreased volumes of imported soybean meal for recipients in the hinterland, the grain terminals owner reorganised the supply chain for this cargo.

The diversification of flow directions has also mitigated the adverse effects of the pandemic on the functioning of the specialised container terminal (E). The reduced trans-

shipment volumes of imported goods (withholding of production in China and of exports from Asia to Europe) were mitigated by the stable exports of products from Central Europe to the Chinese market (increased demand for imports in China). The terminal positively related to the increased needs in the area of container stripping, which were observed in the initial phase of the pandemic.

Limiting the possibility of taking active measures by the terminals resulted from their high specialisation and focus on transshipment service. Those terminals have limited storage capacities, therefore they may not create or handle any supply chains by means of the storage function. It is also impossible for them to change supply chains, as there is no capability of handling cargoes other than those dedicated. It is particularly visible in the case of the container terminal, whose transshipments are closely dependent on decisions (made during the pandemic) of shipping operators whose ships are served by the terminal. However, it should be added that those terminals operators were convinced that the volumes of handled cargoes would soon be back to the levels from before the pandemic. The conviction was justified by the nature of the handled cargoes (soybean meal is the most commonly used feed) or the position held by their suppliers in the global trade (China as the global exporter of many processed goods).

Figure 3 presents a diagram showing the dependency between the type of terminal and its main function, and the tactical decisions adopted by the interviewed terminal operators.



Key:



Change of Flow Directions



Change of Maritime Supply Chain



Change of Storage Time

Figure 3. Kind of tactical decisions of terminal operators, depending on the type of terminal and its main function.

5. Discussion

Our research results made it possible to verify and extend the studies done so far on decisions made by port terminals operators in response to the effects of the COVID-19 pandemic, reflected in changes or disruptions in the maritime supply chain functioning.

Our research has confirmed the findings of Michail and Melas [62], which have shown a significant impact of the pandemic on freight rates in maritime transport of dry and liquid bulk cargoes. Additionally, our research has shown drops in port transshipment volumes of many dry bulk cargoes, and extension of storage time for petroleum products, which contributed to lower transshipment levels at the terminals.

The results of our study are also compliant with those obtained by Fernandes [6]. We have also identified cases where the existing maritime supply chains were frozen (i.a. imported steel products, exported coke). Moreover, our research has shown that as a result of the COVID-19 pandemic some of the maritime supply chains ceased to exist (e.g., the imported iron ore supply chain, as a consequence of closing down the smelting operations in the hinterland). Besides, some of the existing maritime supply chains were sustained, but with reduced cargo levels (i.a. exported steel products), and others changed their routes and volumes. The COVID-19 pandemic accelerated the changes in the economy that resulted from the climate policy, first and foremost the ones connected with phasing out any energy-consuming and carbon-intensive production plants.

Our research has also shown that in the case of some maritime supply chains there were some transshipments volumes that actually rose during the COVID-19 pandemic (i.a. imported cellulose). What is more, some new MSCs came into being, in connection with cargoes that the studied terminals had never handled before or had handled them on a much smaller scale (e.g., exported wood).

Our findings have also confirmed the study results (i.a. [19,20]) that pointed to considerable uncertainty regarding the future of supply chains, predominantly those of dry bulk cargoes. Moreover, our research has indicated that the uncertainty was related to not only withholding or closing down the production in the ports' foreland and hinterland (see the industries using steel products), but also to problems connected with work organisation in other seaports (see the example of the Argentinian ports serving soybean meal exports).

In turn, our research results only partially confirmed the study results presented by Notteboom and Haralambides [14], which showed reductions in port transshipment volumes all over the world in the first phase of the pandemic. Our research results have confirmed distinct drops in transshipment volumes at the container terminal (as a result of the lockdown in China) and at the universal terminals handling various dry bulk cargoes and conventional general cargoes, mainly connected with the steel industry. At the same time, our results have revealed that some terminal operators compensated the decreased transshipments in one flow direction with increased transshipments in the other (grain terminals, conventional general cargo terminal). Another finding of our research is that the terminal operators whose activity consisted mainly in storage (fuels, frozen cargoes) should not be assessed in terms of the volume of handled cargoes. At these terminals, changes in storage periods took place.

Our research study has also confirmed the impact of the COVID-19 pandemic on changes in handling the seaport hinterland transport [48]. Additionally, we found that the problems encountered by road transport operators at border crossings during the pandemic as well as decreased passenger traffic in the railway infrastructure increased the attractiveness of rail transport on the routes to/from the hinterland.

Our findings are concurrent with the study results and recommendations of van den Oord et al. [49] and Tijan et al. [59], and stress that as a result of the COVID-19 pandemic it is now necessary to review the way organisational networks like seaports are managed, and to accelerate digitisation of ports.

However, our findings did not unambiguously validate the results obtained by Russell et al. [50] indicating that containerised general cargo supply chains were characterised by increased uncertainty in relation to other groups of port cargoes. According to

our study, increased uncertainty about the future and durability of MSCs pertained to dry bulk cargoes and conventional general cargoes connected with the steel industry. The representative of the deepwater container terminal covered by our study positively assessed the transshipment prospects for the near and further future, which is concurrent with the findings of Notteboom et al. [52]. That assessment was a consequence of the position and competitive advantages held by China in the global economy and international trade. The quite quick resumption of the industrial activity in China made it possible to compensate at the end of 2020 the drops in transshipments experienced in the first half of the year. Additionally, at the time of temporarily reduced transshipments of containers with goods imported from Asia, the exports of containerised goods to Asia remained at a stable level. Our research findings have confirmed the significance of measures taken by the terminal operator [41,50] to counteract the effects of the COVID-19 pandemic, in particular with regard to storage periods and number of container stripping operations.

Our findings are also coherent with those obtained by Notteboom et al. [52] with regard to resilience of the demand for basic goods, especially foods and medical products, as well as considerable adaptation capabilities of container terminals.

6. Conclusions

In the course of the pandemic, the port terminals operators were faced by a number of challenges resulting from the changes that took place in maritime supply chains, both in the foreland and hinterland, as a result of the pandemic. Some maritime supply chains ceased to exist, some of them were operating with decreased cargo volumes, while in other cases the transshipment volumes actually rose during the COVID-19 pandemic. Also, some new MSCs came into being in connection with cargoes that the analysed terminals had never handled before or had handled them on a much smaller scale.

Those factors influenced the size and structure of port transshipments and/or storage periods. Our research findings have demonstrated that the scale and nature of the impact of those factors varied depending on the terminal type (universal or specialised) and on the main function played in the maritime supply chain. Thus, the main contribution of the presented study is identification of sources and types of disturbances observed in the various maritime supply chains caused by the COVID-19 pandemic and their impact on the operations of various types of seaport terminals, namely those serving bulk (universal, specialised) and general (universal, specialised) cargoes. As a result of conducted research the dependency between the type of terminal and its main function, as well as the tactical decisions adopted by the terminal operators have been identified. Our research study revealed that the extent of engagement and tactical decisions undertaken by the terminals operators during the pandemic were depended on the type of terminal (universal or specialised) and its main function played within a supply chain.

It was found that there were significant reductions in port transshipments of many dry bulk cargoes and general cargoes related to the steel industry, which meant lower transshipment volumes at the terminals. The uncertainty was related to not only withholding or closing down the production in the ports' foreland and hinterland, but also to problems connected with work organisation in other seaports.

The tactical measures taken by the terminal operators in response to the changes in the MSCs being the effect of the COVID-19 pandemic were classified as follows: (1) pro-active measures (e.g., changing the maritime supply chains), where terminal operators took actions focused on engagement in new (so far non-existent) maritime supply chains, or even establishing them, and (2) adaptive measures, where the terminals merely reacted to disruptions in the existing maritime supply chains, caused by the COVID-19 pandemic in the port's foreland or hinterland.

Our research findings have demonstrated that the highest activity level was shown by two universal terminals whose dominating function was cargo transshipment. Specialised terminals whose main function was the transshipped cargo storage made decisions that helped them adapt to the changes the pandemic brought in the port's hinterland or foreland.

The COVID-19 pandemic also led to other needs related to storage. In the case of the specialised terminals focused on transshipment, the changes resulting from the pandemic mainly led to changes in the directions of cargo flows.

Moreover, our research findings unambiguously confirm that it is important for port enterprises to be flexible in adapting to the changing circumstances. This was manifested in the described actions focused on maintaining the served supply chains (even during temporary falls in transshipment levels) or on compensating the temporary or total losses connected with the decreases in transshipments of certain cargoes, increased engagement in serving other/new cargoes or the same cargoes, but in a different flow direction. The flexibility was also connected with the need to adapt to the changing needs connected with cargo storage time, i.e., extending or shortening the storage period.

The flexibility of port enterprises in adapting to the changing circumstances is essential for the sustainable development of MSC, as well as ensuring of global energy markets sustainability. Seaports as essential nodes of global energy supply chains enable not only greater flexibility, but also diversification of energy resources supplies (e.g., different types of raw materials, supply directions, etc.) comparing them to deliveries with the use of pipeline transport only (its economic viability). Diversification of supplies increases deliveries safety required by customers and social equity. The involvement of eco-friendly maritime transport as an alternative to deliveries of energy resources using land transport modes (rail, road) also decreases the external costs of transport spent, for example, on environmental protection. The Authors' previous research showed that the shift from land to maritime supply chains of biomass could reduce the CO₂ emission several times [75].

The multi-case study method applied in the research made it possible to identify the sources and kinds of disruptions observed in various maritime supply chains as a result of the COVID-19 pandemic and their impact on the operations of various types of seaport terminals. However, the adopted methodology has its constraints. The findings obtained as a result of the study may not be fully generalised (statistical generalization). Nevertheless, the findings may be partly generalised with the meaning of analytic generalization [69]. Presented research results may facilitate decision-making processes by operators of different terminals in case the similar disruptions occur in future. Depending on the type of terminal and its prevailing function in a seaport, the terminals operators may undertake specific types of activities related to the change of cargo storage time, intensification of transshipments in different relations or acquisition of new cargoes. Based on the research results the recommendations may be made for operators of various types of terminals performing activities within the MSCs, including:

1. Specialised terminals operators with prevailing storage function—it is necessary to respond to new needs of customers related to the extension or reduction of storage time and possible intensification of transshipment operations in specific time periods;
2. Specialised terminals operators with prevailing transshipment function—it is recommended to maintain the current service capacity despite temporary suspensions or limitations of deliveries; taking actions aimed at compensating for the decrease in cargo transported in one relation by an increase in cargo handling in another relation;
3. Universal terminals operators—it is suggested to take active measures aimed at replacing cargo (whose volume has been significantly limited) with new loads or cargo already handled but coming from new customers.

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