Determinants of further development and management of modern global maritime containerization (Redefinition after Covid-19 and War in Ukraine)

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Abstract

Maritime containerized shipping has recently suffered from various problems and challenges caused by stochastic shocks such as the Covid -19 pandemic or the war in Ukraine. The pandemic and recent war have clearly indicated shortfalls and weaknesses of maritime containerization and have triggered various attempts at identifying the potential for its further development determined by the new reality (after global shocks and with the consideration of new ones).

The paper presents a holistic analysis of factors that globally affect the potential for further development of containerized maritime transport. The entire research design comes as an attempt made at identifying and updating the determinants and predictions of prospects for development of containerization in the current geopolitical situation and global trade conditions in the post-pandemic era, also taking the aspects of the ongoing Russian invasion in Ukraine and the post-war recovery into consideration.

The results of the research are presented as a matrix of the eight main determinants Det 1-8 (each supported by two key factors F1, F2) that have been originally identified. Each factor is described by an originally developed calculation methodology (as an Index). The indexes are calculated for the period of 2018-2020 and subsequently discussed. Moreover, there is a potential for further utilization of the presented matrix as a universal tool that will define the future aspects of management in the field of the expected architecture of global supply chains and maritime transport of containerized cargo after the absorption of global shocks.

1. Introduction

The dynamic development of trade in the world generates additional demand for containerized cargo shipping. Taking the progress of globalization into account (longer distances and growing cargo volumes), cargo becomes predestined to be transported by sea and this fact, in turn, encourages ship owners to enlarge their fleets of container ships. The increased supply of maritime transport services (sailings, container slots) results in the secondary pressure imposed on trade volume. In this way, it is possible to observe a "self-winding" spiral of development (a sustainable path of growth) in the global trade volume, which partially explains the economic phenomenon of modern maritime containerization (Miler, Gostomski, Nowosielski, 2023).

Identified in contemporary literature, the key factors (determinants) of development of containerization in maritime transport are: the dynamically changing market and geopolitical environment (illustrated by the relations between North America, Asia and Europe, so called "the triad regions") (Jackson et al., 2020), advancing internationalization and standardization of trade relations (based on such standards as Incoterms or ISO for containerization) (Becha H. et al., 2020), globalization of international trade (measured by the growth of the foreign trade volume) (Ghosh, 2020; Papava, Chkuaseli, 2021; WTO, 2020), the specific role of maritime transport in international trade (accounting for 90% of the volume of transported cargo) (Notteboom, Pallis, Rodrigue, 2021; Madhav et al., 2017; Menhat

et al., 2021; Irakli, 2021, p. 5), universality of information technology (IT), information and communication technology (ICT) in telematics systems (Matczak, 2013; Kim, Kim, Kang, 2022) and pressure to protect natural environment, including the concern about zero emission transportation processes (decarbonization of shipping and port/terminal operations) (Cullinane, Yang, 2022; Lindstad et al., 2021; Cullinane, Haralambides, 2021). All these factors had been monitored separately and controlled against potential risks and till the end of the year 2019 nothing suggested an incoming catastrophe. In 2019 the development of containerized cargo transportation free from any significant risk was dramatically interrupted by the risk factors of the stochastic nature, such as the Covid-19 pandemic and, a more recent one - the war in Ukraine (lasting for more than a year since Feb 2022). These two economic and geopolitical factors have almost immediately caused destabilization to global, European, and local trade (including the occurrence of difficulties in maritime containerized transport), exposing all the weaknesses so far hidden from the global audience (Miler, Gostomski, Nowosielski, 2023).

The objective of this study is to evaluate a possibly larger set of determinants that can affect global containerized shipping in the light of deep shocks that have recently occurred to the global economy (the pandemic and the war in Ukraine). Specifically, this study is aimed to verify whether a holistic analysis and identification of the factors can help in further better prediction of the potential for development of maritime containerization and also whether the presented matrix of determinants/factors can come as a useful tool for the preparation to absorb any future shocks to global economy and supply chains. This study is distinct from previous ones as it examines widely all the aspects and identifies the determinants as a whole (one matrix) in much more a holistic approach, focusing not just on one selected factor but on a set of factors combined as a one tool. In addition, it clarifies and introduces a methodology for the calculation of each factor describing the eight main determinants. Through this, it may be possible to evaluate the status of the potential of maritime containerized transport as a whole on an annual or quarterly basis. Therefore, the Authors have decided to take this opportunity and launch research on this field in order to fill in the cognitive gap that has been identified.

Taking the entire structure of the presented paper into account, Section 2 addresses the importance of stochastic shocks for the potential of maritime transport of containerized cargo with special emphasis focused on the Covid-19. It also identifies challenges to the development of maritime containerized transport. Coming as the actual first stage of entire research, by the synthesis of the existing trends and challenges, Section 3 identifies the main determinants (presented as Det 1-8) and subsequently assesses two main factors (F1, F2), clearly indicating the nature of the particular determinant; finally, the section presents the matrix of Det 1-8. Section 4 introduces the volumes of the factors (F1-F2) and Indexes calculated according to the adopted formulas for the years 2018-2020 (2018=100). Finally, in the Conclusions, it is suggested that Det 8 (capabilities for further digitalization and computerization of maritime and container operations) becomes one of the most important determinants of further development of maritime containerized transport. There is also an analysis presented (that involves Det 1-8) and it comes as an original and promising research tool for providing a holistic analysis of determinants driving the development of containerized shipping.

2. Literature review

2.1 The impact of the Covid-19 and the war in Ukraine on global maritime transport of containerized cargo

According to current research (Notteboom, Pallis, Rodrigue, 2021), containerized transport comes as a fundamental sector in almost every country in the world. Containerized shipping is a global sector and a part of the global supply chain to most industries. Since the outbreak of the Covid-19 pandemic in China, global economy has been disrupted. The pandemic has distorted processes taking place in global markets. Considering an unprecedented lockdown of almost all the countries, economic activities in the entire world have been significantly decreased (UNCTAD, 2021). According to the International Economic Organizations, in 2020 (the pandemic year) most countries recorded negative results as far as their GDPs were concerned. The Covid-19 pandemic has also considerably affected global economy in terms of global economic growth, world trade, economic development, and challenges to economic policy (WTO, 2020). During the pandemic, Central Banks, International Monetary Bank, World Bank, and other financial

institutions were forced to revise their monetary policies (Jackson et al., 2020). The pandemic came not only as a crisis to public health but also as a factor negatively affecting global economic conditions by loss in human life, decreased productivity, closing down companies, distortion in trade and massive disruption in the sectors of industry and tourism (Ghosh, 2020). The sudden shut down of numerous factories and production plants resulted in considerable disruption of supply chain management (Menhat et al., 2021; Megableh, 2021).

Economic shocks test the resilience and adaptability of the shipping industry and container ports. Each crisis triggers various ramifications in the container market. However, as far as the Covid-19 pandemic was concerned, the situation was very different since it involved an external shock that rapidly impacted all the elements of supply chains approximately at the same time (Notteboom, Pallis, Rodrigue, 2021; Guerrero, Letrouit, Montes, 2022). Furthermore, planning the development of containerized shipping and managing the global supply chains were made even more difficult since the Russian invasion in Ukraine.

In April 2020, a lockdown was imposed on 4.2 billion people (54% of the global population) by a number of governments in order to prevent the pandemic from spreading. It negatively affected 90% of economic activities in the world and it was the most acute for the service sector. Over 100 countries closed their borders and, as a result, international trade relations were dramatically limited. Death of numerous employees, high incidence of coronavirus infections, necessity of staying at home for thousands of people who had to undergo the quarantine procedures reduced dramatically the supply of workforce at places where business activities had not been stopped.

A decrease in production in China resulted in a decrease in export and, in this way, it contributed to a reduction in container handling at Chinese ports – in February 2020 it fell down by 18% in comparison to the previous month (Abel-Koch and Ullrich 2020, p. 1–2). It should be emphasized, however, that global trade had suffered from weakening much earlier, during the entire period, from the beginning of the financial and economic crisis of 2008 to 2020, mainly because of some stronger protectionism tendencies in global economy and the trade war between the USA and China. In 2018 the total global export and import of goods in relation to the global GDP was 51% and in 2019 it dropped down to 43% (UNCTAD, 2020). Breaking international supply chains during the Covid-19 pandemic only accelerated de-globalization processes observed in global economy.

The lower global trade volume indicates less containerized cargo, lower demand for containers and container vessels and a lower number of containers handled at ports and transported by sea. According to Clearkson Research, global container handling at seaports in March 2020 was 5% lower than it was in March 2019. A decrease in the global trade volume year-to-year in April 2020 was 3% and in May it was 7% (ISL Shipping Statistics and Market Review, 2020, p. 5–8).

During the first half of the year, the oversupply of container vessel tonnage resulted in a decrease in charter rates charged in the market of container shipping. Charter rates for large container vessels became the lowest. Considering container vessels of the capacity of 8500 TEU, a daily charter rate dropped by 48%, from USD 29 600 to USD 15 400, from the beginning of 2020 to May 2020. Shipping containerized cargo was most affected along the routes between China and Europe. It appeared that ship owners withdrew container vessels tonnage which exceeded the drop in the demand for shipping containerized cargo from the market. This situation was overlapped with serious problems resulting from the lack of empty containers in Asia and, first of all, in China. It should be noted that there is structural imbalance in container transport between China and Western Europe and the USA. Traditionally, more loaded containers came from China to European and American ports than the other way around. This disproportion was usually neutralized by repositioning empty containers to Chinese ports. However, during the pandemic this process was disrupted. Container shippers had to compete for containers and as a result freight rates were considerably increased in container transport with China (Youd, 2021).

As a result of that turbulence, a huge increase in freight rates, fees for chartering container vessels and option costs for construction of new vessels (especially considering the necessity of adjusting propulsion systems to the strict requirements for lower emission) was recorded. At the beginning of September 2021, Shanghai Containerized Freight Index, which presents freight rates in trade with Chinese ports, recorded an increase by 449% in comparison to the analogical period before the pandemic (September 2019)

(Hellenic Shipping News, 2021). During the third quarter of 2021, A.P. Moller-Maersk recorded a gigantic increase in the net income for its operational activities: it reached the level of USD 5.461 billion in comparison to USD 0.947 billion recorded for the analogical period in 2020 (ISL Shipping Statistics and Market Review, 2020, p. 5–6).

The Covid-19 crisis has also affected the shipyard industry. During the first quarter of 2020, shipyards obtained only 13 orders for new container vessels and in April 2020 they did not receive any orders at all (ISL Shipping Statistics and Market Review, 2020, p. 5–6). Vessel crews were also put in a very difficult situation because of the pandemic. Each month about 150 000 seamen were supposed to be replaced. During the pandemic they faced sanitary restrictions concerning disembarkation, cancellation of air flights, problems with visas due to the fact that consulates, where visas for seamen are usually issued, were closed. As a result, thousands of seamen were stuck on their vessels. Working at sea during the subsequent months, without any possibility to see their families resulted in growing frustration and it negatively affected the quality of seamen's performance (UNCTAD, 2020).

At the beginning of 2022 some other significant circumstances occurred, posing a threat of destabilization to European (and global) trade (including maritime containerized transport). On 24th February 2022 another war broke out when Russia invaded Ukraine (after the annexation of Crimea in 2014). Intensified war operations were launched, bringing destruction, and severely affecting Ukrainian people, who bravely fought back against the invaders. The unprecedented Russian aggression (at present amounting to what is considered war crimes and genocide) faced the response of all the community of the democratic world in the form of various economic sanctions imposed on Russia. The prices of strategic raw materials rocketed skywards, the levels of strategic reserves in numerous European countries turned out to be too low and logistic supply chains to and from Russia were practically and largely stopped. The intention of the countries imposing sanctions on Russia (Europe and the United States of America) was to isolate that country politically and also to weaken it economically, causing its economic bankruptcy and, at the same time, providing strong political and economic support to Ukraine (including armament supplies on enormously large scale). At the end of the February 2023 the military conflict remained unsolved. Assuming that the sanctions and the resistance of the Ukrainian army and civilians will bring positive results and, despite a partial (or in a less optimistic scenario: complete) annexation of Ukraine, Russia will be forced to withdraw from Ukraine, facing its own political and economic (and possibly military as well) bankruptcy. Undoubtedly, in any predictable future, it should pave the way for the process of dynamic reconstruction and recovery of Ukraine (in a formula of a democratic country following the rule of law). The United States of America and European countries have already declared their financial, material, technological (know-how) and political support on an unprecedented scale in history, that can be counted in EUR/USD billions. Most probably, a major part of the material support will be transported by sea to container terminals in Ukraine (Odessa, Yuzhnyy, Chornomorsk). It should bring international maritime containerized transport back to the Black Sea (on the day when the Russian invasion was started, the terminal in Odessa was closed because the control over shipping on the Black Sea was seized by Russia, also because the Ukrainian ports were blocked and the military threat on the sea was very high as well as a big part of Black Sea has been mined). The scale of the economic sanctions imposed on Russia and their influence on trade (including maritime transport of containerized cargo) between Russia (after the war) and EU countries and the USA are at present impossible to be assessed during the current stage of the conflict.

2.2 Identification of challenges to the development of maritime containerized transport

Caused by the Covid-19 pandemic, a rapid decrease in the volume of global trade also resulted in a considerable loss of time in port operations (Narasimha, Jena, Majhi, 2021). It occurred because the volatility of the international trade volume comes as one of the most important variables that directly affect the efficiency of container ports (Xu, Yang, Chen, Shi, 2021; Toygar, Yildirim, İnegöl, 2022, p. 4). During the first half of 2020 the quarantines imposed at ports and limited numbers of port employees who provided services caused an increase in container transport costs (Menhat, 2021; Qiao, 2021, p. 2).

Also, the container industries faced a number of new challenges in 2019, such as trade regulations (e.g.: the trade war between the USA and China), shipping fleet deployment, green shipping, and green

port issues (e.g.: Sulphur content in fuels). The emergence of Covid-19 also brought new challenges to shipping operations and management, such as: port security check can result in extra waiting time for berthing operations, inland seaport transshipment operations, hinterland transportation management, etc.

Container shipping has increasingly found itself facing political and economic challenges and risks. These include stricter environmental regulation, capacity bottlenecks at ports, raising fuel prices, raising inflation and protectionist tendencies (Yazir et al., 2020, p. 260).

Hence, it should be noted that the sector of container shipping faces numerous challenges that may limit its growth capabilities (Yazir et al., 2020, p. 261):

maritime shipping has become of an interest to national and international climate and environmental policies; there is an on-going discussion about various measures that can mitigate the negative impact exerted by shipping on natural environment (e.g., CO_2 emission and pollution). These measures include emission trading, efficiency standards, restrictions to Sulphur content in fuels. Shipping lines will incur higher costs in their operations because they will have to invest money into the development of their fleets in order to adapt and follow new standards.

there are very narrow bottlenecks at ports (e.g. terminals, inland water shipping) that can result in long waiting time for container vessels; insufficient depth of water areas inadequate for container shipping may become an impediment to its development; growing significance of very large container vessels requires deepening of waterways/fairways necessary in numerous ports; development of port infrastructure required by the transport industry is often insufficient because of financial limitations or political issues;

still posing treat a number of pirate attacks in some maritime areas (recently also outside Western Africa; a report presented by IMB 2020) means higher costs for ship owners, for example insurance and vessel modernization costs (e.g., installation of crew shelters) (Wong, Yip, 2012, p. 306).

personal costs have been increased because of the Covid-19 pandemic; the availability of qualified personnel in the middle- and long-term perspectives has become a challenge to the entire sector.

Ultimately, however, global container shipping will remain the fastest growing mode of transport over the medium-term (Wong, Yip, 2019). Considering the general lines of changes taking place in transport and presenting their further synthesis, it should be assumed that in the subsequent years the competitiveness of maritime transport of containerized cargo and capabilities for its further development will be decided mostly by the groups of factors, such as digitalization, automation, autonomation and protection of natural environment (Miler 2016, 148–149).

3. Research methodology

3.1. Identification of determinants

The first stage of the research is, by the synthesis of the existing trends and challenges, to identify the main determinants (presented as Det 1-8) and subsequently (stage 2) to assess two main factors (F1, F2), clearly indicating the nature of the particular determinant (stage 2, end note: all the determinants are equipped with the defined specific F1/F2 and Index formulas). As soon as a basic methodology is prepared, the matrix of determinants will be challenged with real data in order to calculate the Indexes which are necessary for further comparison and synthesis.

In order to provide a synthetic approach toward all the potential for further development of containerization processes in maritime transport, the following key determinants (indicating the growth limits), should be stated:

capabilities for further growth of international trade volumes (in the context of economic and geopolitical relations, implemented terms of trade and disturbances caused by the pandemic) – limits to international trade.

capabilities for further development of container vessels (in relation to their size given in TEU and the limits to the economics of their use) – limits to container ship capacity.

capabilities for the supply of new containers (in relation to the capabilities of the industry responsible for container construction) – limits to the container volume.

capabilities for further development of terminal infrastructure (in relation to the size, expansion, levels of competitiveness and operational efficiency of container terminals) – limits to container terminal capacity.

capabilities for further development and capacity of maritime transport infrastructure (in relation to navigation sea routes and canals, especially the Suez Canal and the Panama Canal) – limits to the capacity of sea communication routes.

the level of safety and security of maritime and terminal/port operations (including both these aspects: safety and security and also safe container turnover) – limits to maritime (container) safety and security.

capabilities for further lowering maritime transport anthropopressure (in relation to a decrease in emission of greenhouse gases – GHG, CO2 and the general lowering of external effects) – limits to the internal costs of container transport.

capabilities for further digitalization and computerization of maritime and container operations (in relation to automation, robotization, autonomation, implementation of IT systems supporting management, the use of database systems, artificial, virtual, and augmented reality) – limits to information management.

3.2. Construction of the matrix of determinants

In the research, each identified determinant is described by two key factors. According to the assumed methodology the selected factors that are presented in terms of their quantity or quality, have been also ascribed with originally prepared calculation and each factor is presented as an Index. The scope of the proposed matrix is depicted in Table 1.

Determinant (Det) Factor (F)		Description	Index	Calculation
Det 1 (capabilities for further growth of international trade volume)	F1	The total global trade	Index of Global Trade $I_{(GT)}$	initially in USD billion, then compared with the basic year, basic year=100; $I_{(GT)}$= 1.0,
	F2	The implemented terms of trade	Index of Trade Freedom $I_{(TF)}$	calculated as the % of freedom "volume", lower $I_{(TF)}$ than more restriction to the global trade imposed (e.g., restrictions, lockdowns etc), [vary between 0.00-1.00]
Det 2 (capabilities for further development of container vessels)	F1	The global container vessel fleet	Index of Container Vessel Fleet $I_{(CV)}$	TEU [thousands], then compared with the basic year, basic year=100; $I_{(CV)}$= 1.0
	F2	The capacity of the largest container vessel commissioned in the particular year	Index of Container Vessel Capacity $I_{(VC)}$	TEU [thousands], then compared with the basic year, basic year=100; $I_{(VC)}$= 1.0
Det 3 (capabilities for the supply of new containers)	F1	Production/supply of new containers in the world	Index of Container Supply $I_{(CS)}$	items [thousands], then compared with the basic year, basic year=100; $I_{(VC)}$= 1.0
	F2	The general number of containers in the international trade	Index of General Number of Containers $I_{(NC)}$	items [thousands], then compared with the basic year, basic year=100; $I_{(VC)}$= 1.0
Det 4 (capabilities for further development of terminal infrastructure)	F1	The number of containers handled at container ports	Index of General Number of Containers	TEU [thousands], then compared with the basic year, basic year=100; $I_{(VC)}$= 1.0

			Handled $I_{(CH)}$	
	F2	The number of container terminals at seaports	Index of General Number of Maritime Terminals $I_{(MT)}$	TEU [thousands], then compared with the basic year, basic year=100; $I_{(VC)}$= 1.0
Det 5 (capabilities for further development and capacity of maritime transport infrastructure)	F1	The number of vessels handled at the Suez Canal	Index of Vessels Handled @SC $I_{(SC)}$	[vessels], then compared with the basic year, basic year=100; $I_{(SC)}$= 1.0
	F2	The number of vessels handled at the Panama Canal	Index of Vessels Handled @PC $I_{(PC)}$	[vessels], then compared with the basic year, basic year=100; $I_{(PC)}$= 1.0
Det 6 (the level of safety and security of maritime and terminal/port operations)	F1	The number of maritime/port collisions and accidents (including those that involve container vessels)	Index of Maritime Collisions $I_{(MC)}$	[reported incidents], then compared with the basic year, basic year=100; $I_{(MC)}$= 1.0
	F2	The number of terrorist and pirate attacks	Index of Maritime Piracy $I_{(MP)}$	[reported incidents], then compared with the basic year, basic year=100; $I_{(MP)}$= 1.0
Det 7 (capabilities for further lowering of maritime transport anthropopressure)	F1	The total CO_2 emission generated by maritime shipping	Index of Maritime Emission $I_{(ME)}$	total CO_2 emission [million tonnes], then compared with the basic year, basic year=100; $I_{(ME)}$= 1.0
	F2	The number of ECA (Emission Control Areas) with limitations to shipping in terms of marine fuel specification	Index of ECA $I_{(ECA)}$	then $I_{(ECA)}$ for the absolutely free shipping without considering emission control is assumed as 1.0 and with the subsequent restrictions it will strive to achieve 0.0 in the years 2030/2050.
Det 8 (capabilities for further digitalization and computerization of maritime and container operations in relation to automation, robotization, autonomation, implementation of IT systems supporting management, the use of database systems, artificial, virtual, and augmented reality)	F1	The number of automated terminals	Index of Automation of Maritime Container Terminals $I_{(AUTER)}$	Index $I_{(AUTER)}$ =automated maritime terminals/total maritime terminals x 100%, [0.00-1.00]
	F2	The number of e-documents applied in maritime container trade and transportation	Index of Digitalization of Documents in Maritime Container Transport $I_{(e\text{-}doc)}$	Index $I_{(e\text{-}doc)}$ =e-doc/total doc x 100% [0.00-1.00]

Table 1. The original matrix of the determinants defined for the development of containerized maritime transport

4. Findings/results

Identified above, the determinants of further development of maritime containerized transport (Det), their factor volumes (F1-F2) and Indexes calculated according to the Table 1 formulas for the years 2018-2020 (2018=100) are presented in a synthetic way in Table 2.

Determinant (Det) / Factor (F)		Year 2018=100		Year 2019		Year 2020	
		Original value	Index	Original value	Index	Original value	Index
Det 1	F1	19549,335	1.0	19014,315	0.98	17648,468	0.90
	F2	GATT	0.75	GATT+USA-PRC	0.65	GATT+USA-PRC+LOCKDOWN	0.45
Det 2	F1	22,012	1.0	22,596	1.03	23,632	1.07
	F2	23, 964	1.0	23,756	1.11	21,413	1.12
Det 3	F1	59,700	1.0	54,650	0.92	35,800	0.60
	F2	552,500	1.0	604,700	1.09	652,350	1.18
Det 4	F1	792	1.0	807	1.02	799	1.01
	F2	975	1.0	962	0.99	942	0.97
Det 5	F1	5,663	1.0	5,321	0.94	835	0.15
	F2	13,795	1.0	13,785	1.0	13,369	0.97
Det 6	F1	2,667	1.0	2,756	1.03	2,547	0.96
	F2	201	1.0	162	0.81	195	0.97
Det 7	F1	740	1.0	692	0.94	635	0.86
	F2	ECAs of North America, the United States, Caribbean Sea, the Baltic Sea and North Sea	0.85	further restrictions were added to the basic regulations in the ECAs at the Baltic Sea and the North Sea	0.75	no new regulations and new ECAs were implemented	0.75
Det 8	F1	4.31	0.04	4.57	0.05	5.20	0.05
	F2 Subindex I(e-B/L)	1.4	0.01	1.8	0.02	2.0	0.02

Table 2. Matrix of containerized maritime transport development determinants with final results

Note 1: The basic factor that liberalizes terms of international trade is the General Agreement on Tariffs and Trade (GATT) which is intended to eliminate trade barriers (WTO, 2018). The GATT regulations in their unchanged formula were applied in the years 2018-2020, hence in order to calculate the value of the $I_{(TF)}$ indicator, this factor is considered as constant. In 2019 regulations referring to the trade war between the USA and China became particularly significant to (containerized) shipping. Furthermore, in 2019, after the *vacatio legis* period, regulations referring to green shipping were implemented. In 2020 other very severe restrictions were implemented in relation to the lockdown and they were strictly followed (especially in People's Republic of China). In the methodology assumed for the discussed research it is assumed that $I_{(TF)}$ for free and absolutely unrestricted international trade and maritime transport of containerized cargo is 1.0.

Note 2: Due to the data unavailability, $I_{(e\text{-}doc)}$ has been substituted with Subindex $I_{(e\text{-}B/L)}$ =e-B/L/total B/L x 100, where B/L Bill of Loading – the most important document in maritime transportation, although operations involving electronic bills of lading (e-B/L) started in the late 1990s, with many companies working with different systems to ensure the originality and uniqueness of the document, as of today, approximately only 2% of all bills of lading issued have been electronic.

Note 3: Due to the data unavailability, starting from the years 2021-22 (partially covering the war in Ukraine) the considerations in Table 2 are limited to the pandemic influence on contemporary maritime containerized transport only.

5. Discussion and conclusions

Presented in the paper, the research indicates the multi-aspect and multi-disciplinary character of the determinants that shape modern maritime transport of containerized cargo. The factors analyzed (Factors

1 and 2) for Determinant 1 (Det 1) clearly indicate a negative influence exerted by the pandemic on the volume of containerized cargo transport, particularly in 2020. The main reason for that involved formal changes to the terms of trade and transport (first of all – the lockdown F2). As far as Det 2 is concerned, in a short time the pandemic neither affected the reduction of the container vessel fleet nor influenced processes of increasing the loading capacities of container vessels F2 (in order to achieve the effect of the economies of scale in the global maritime transport); during the analyzed period of time loading capacity increased by almost TEU 600 and in 2023 it has already exceeded the level of TEU 24K; a more serious crisis that concerns the number of container vessels appears in a long-term perspective (not included in the research analysis). Some serious consequences of the pandemic are observed for Det3 where the data indicate a 40% decrease in the production of new containers (2020, in comparison to the period of time before the pandemic). However, also in 2020 there was an increase of 18% approximately recorded in the general volume of containers in trade (mostly caused by reintroducing containers that had been temporarily withdrawn, into trade and increased pressure on repositioning). As far as Det 4 is concerned, the research indicates the resilience of the system applied to terminal productivity control against the stress caused by the pandemic (a slight increase by approximately 2% in the volume of cargo handled at ports with an inconsiderable decrease in the number of terminals at the same time).

The pandemic exerted some significant influence in terms of Det 5 (correlated with Det 1) involving the number of vessels handled at the Suez Canal (F1) where a decrease in relation to the base year was over 85%; a significantly smaller decrease was recorded for the Panama Canal (only 3%); it indicates a total collapse of logistic supply chains in 2020 between Asia and Europe. Det 6 (both F1 and F2) indicates that the pandemic did not affect the number of maritime accidents and the number of pirate attacks. These numbers have been decreasing (however, its correlation with the pandemic cannot be proved at this stage of the research). Det 7 indicates a successive decrease in the CO2 emission (Det 7/F1) which comes as a result of the policy pursued in order to achieve zero-emission and does not indicate any correlation with the consequences of the pandemic. Similarly, F2, the value of which presents the implementation of the subsequent ECAs that decrease emission. The last determinant (Det 8) is indisputably related to the consequences of the pandemic as it determines the necessity of applying solutions that pertain to automation at maritime container terminals (F1). It comes as an antidote to the shortage of workforce and restrictions following the lockdown. An indirect relation to the pandemic can be observed in the necessity of implementing e-documents to trade (considering remote work/home office implemented during the pandemic at an unprecedented scale and often applied at present). Unfortunately, the research also indicates very low coefficients of terminal automation (at the level of 5%) and documentation digitalization (at the level of 2% for e-B/Ls). At the same time, Det 8 becomes one of the most important and most promising determinants of further development of capabilities of maritime containerized transport. Utilizing the presented matrix, the capabilities for the development of maritime containerized transport $P_{(CS)}$ may be calculated (for further comparisons) with the equation as follows:

$$P_{(CS)} = f\ (Det_{(n;\ n=1\text{-}8)}\ F1, F2) \quad (1)$$

where:

$Det_{(n;\ n=1\text{-}8)}$ - determinants for Det1-8

F1 - factor 1 for the n determinant

F2 - factor 2 for the n determinant

At this stage of the research, it is possible to state that the discussed analysis that involves eight determinants (Det 1-8) comes as an original and promising research tool (that obviously requires further specification and improvement) for providing a holistic analysis of determinants of development of containerized shipping, with the consideration of challenges characteristic to the era of sustainable development, digitalization, automation and frequent turbulences (stochastic occurrences, global shocks such as the pandemic or the war in Ukraine).

To sum up- the Covid-19 pandemic has short- and long-term impact on the global container shipping industry with a necessity to adapt to some possible changes in the global supply chain system. Intensified inspections of containerized cargo transported by sea, including delays at border checkpoints and complex procedures have already increased costs of global logistics services. Considering temporary trade barriers and export restrictions, some possibilities have appeared to increase alternative logistics

solutions, such as intercontinental railway services that can streamline trade between the East and the West. Unfortunately, because of the war in Ukraine those solutions have proved to be of temporary nature. After a long time, in the market of containerized cargo transport it is possible to expect some acceleration of digitalization development, increased investment in new technologies supporting automation trends in this sector. An increase in the levels of containerization and global capacity will be possible in the sector of container shipping. However, it is expected that larger vessels will be commissioned along with more efficient loading and unloading systems at port terminals. Considering the experience acquired during the pandemic related to limited production and shipping, the models of production and implementation of logistics services may be changed from the Just-in-Time to Just-in-Case. The maritime industry, including the container shipping sector, will have to adapt itself to the upcoming changes. Perhaps, it will be necessary to consider the development of shorter supply chains, increased implementation of alternative logistics solutions such as intercontinental railway services or multi-functionality of warehouses in the vicinity of markets that will be required to shorten the transit time to various destinations.

Considering the above-mentioned arguments, issues related to the development of the geopolitical situation and global trade conditions, it is possible to draw five general conclusions that determine future (post-Covid and after the war in Ukraine) governance in the field of international (global) supply chains, directly affecting the shape of international maritime transport of containerized cargo:

it is highly probable that a re-configuration of supply chains and international exchange will take place, considering tension between China and the USA, the expansive policy of China in the development of the New Silk Road, the search of new locations for production and distribution, based on the re-orientation of trade policy pursued by the "triad" entities (North America, Asia, Europe); this will result in shortening and making current supply chains more flexible (new "geography" of connections);

it is highly probable that production locations will be closer to potential sales markets; this will result in a re-configuration of current production locations which have been so far dominated by the strong economy of China.

it is highly probable that new guidelines concerning the amounts of reserves and flexibility of production and supply chains will be issued by the "triad" entities and countries directly affected by the war in Ukraine; this will result in an increase in reserves at the particular stages of logistics processes, in a change in the attitude toward obligatory (strategic) reserves and also in a necessity of increasing national reserves (which, in turn, will increase pressure on storage area, warehouse surface, cargo handling capacities of port terminals, etc.);

most probably, international logistic supply chains of transporting containerized cargo to Ukraine by sea will be ceased until the end of the military operations; after that a high dynamic in the turnover growth will be observed due to the implementation of reconstruction and recovery schemes.

most probably, international logistic supply chains of transporting containerized cargo to and from Russia by sea will be constantly limited to their minimal levels, in accordance with the policy of sanctions becoming stricter and stricter. At present, the situation after the war is impossible to predict.

6. Limitations and directions for future research

Considering the stochastic character of economic phenomena and shocks, the discussed research indicates the practicality of applying a holistic analysis of factors that determine capabilities for the development of containerized shipping. In the light of the specialist literature, such analysis has not been currently provided at such a comprehensive scale. The Authors will continue their research studies, focusing on more adequate selection of the factors F1 and F2 applied to describe determinants, also on a more detailed source query in search of relevant information. So far, the most discouraging factor in the research has been the lack of specific information on containerized shipping referring to numerous processes of the modern era (digitalization, automation, sustainable development). This fact has considerably limited an adequate selection of indicators at this stage of the research. A more adequate dimension of the research will be possible by adding the data of 2021 and 2022 to the analysis. This will allow the Authors to present the usefulness of the discussed tool (also for a discussion of the negative consequences of the war in Ukraine) and to indicate more precisely the fields for the potential

development of containerized shipping. In the next stage of this research, it is planned to introduce methodology (based on the Logistics Performance Index – the LPI of the World Bank), where all the Factors/Indexes will be weighted, and the assessment will be conducted to obtain an ultimate synthetic numeric description of all the determinants in the particular years. Subsequently, the numeric descriptions of all eight determinants will be set in the radar charts that present the capabilities for development in the particular years. In the final stage of the analysis, the particular radar charts for the subsequent years will be superimposed on each other in order to indicate graphically differences and areas/factors that determine the development of maritime containerized transport in the most significant way.

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