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Modernisation of Container Ship Fleets: State of Play and Consequences for the Baltic Sea

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ABSTRACT: In order to adapt to structural changes in world trade, container ship owners have developed their transport services. Thus, the unit transport capacity of container ships has been multiplied by 3 in the space of 20 years. The maritime transport of containers has developed very speedily and there have been changes in the strategies of shipping companies.
These giants of the seas, put into service on the maritime trades linking the world's main production and consumption markets, have led to the repositioning of ships on secondary maritime spaces. This is known as cascading. The objective of this paper is to study the impacts on the ports and the maritime network of the Baltic Sea. For this purpose, we will carry out an analysis of the evolution of container ship calls from 2012 to 2020 (number of calls, capacity offered in calls, ...) followed by a graph analysis to study the evolution of the maritime network.

1 INTRODUCTION

Since the 2000s, the size of container ships has grown exponentially. The maximum transport capacity was 8,000 TEU (twenty-foot equivalent unit) in 2000 for ships 300 metres long, compared with 24,000 TEU today. The unit transport capacity has tripled very quickly. As a strategic crossing point between the Atlantic and Pacific Oceans, the Panama Canal's "Panamax" locks limited the growth in container ship size. The economic and, above all, industrial development of East Asia under the impulse of China has placed this area at the centre of world flows of goods, particularly containerised goods. East Asia has emerged as the new lung of international trade but also as the heart of the global container system [1]. The major container ship owners have adapted their transport offers to respond to this evolution in world trade. The main shipping routes are now linking East Asia to Europe and North America. Passage through the Panama Canal has been found to be unnecessary. The increase in the size of container ships was therefore no longer confronted by the increase in the size of the locks in this canal. From the point of view of shipbuilding engineering, the limit of the size of container ships has not yet been reached, but it will be limited by the size of the port infrastructure (draught, length of quays, capacity of gantries, etc.), which cannot keep up with this development at the same speed. Containerised maritime transport has therefore developed very speedily and has undergone major upheavals in maritime organisations and operators' strategies in recent years.

After presenting the framework of our study and the evolution of the container ship fleets, we will zoom in on the impacts on the maritime container ship network and on the calls to the Baltic Sea ports.

For this paper and analysis, we use data from the IHS fairplay database which provides us information

on the technical characteristics of the ships (operators, maximum transport capacity, draught, ...) and on the movements (port of call of the ship and date and time of arrival and departure). This database is presented in more detail in a separate section.

2 STUDY FRAMEWORK

To respond to the development of international trade and their growth needs, shipping companies have, since the 2000s, ordered new and larger ships (fig. 1). Currently, the largest container ships have a unit transport capacity of 24 000 TEU, compared with 8 000 TEU in 2000. These very large ships allow shipping companies to achieve economies of scale and reduce construction and operating costs per container carried. New categories of container ships have appeared and the world's major shipowners have all rapidly equipped themselves with these giants of the seas. For the new-panamax and above categories, for example, we have gone from 173 ships in service in 2016 to 313 in 2020.

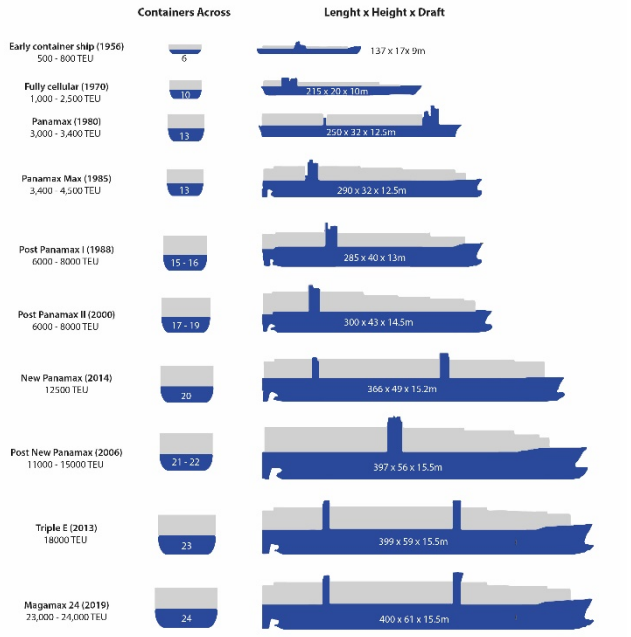

Figure 1. Containerships categories. Production: Ronan Kerbiriou, February 2021.

These large ships are positioned on the main global shipping trades linking East Asia to Europe and North America. This concentration and increase in shipping supply has led to the decommissioning of smaller vessels. Many vessels that used to operate on its major international trades and are now of intermediate size, have been repositioned on secondary shipping lines and other smaller shipping areas. Larger container ships have replaced smaller ones. This is known as cascading and has therefore had an impact on the container traffic of Baltic Sea ports. This is the subject of this article, in which we will look at the impact of the increase in the size of the container ship fleet on the Baltic Sea ports. To this end, we will analyse the evolution of container ship calls from 2012 to 2020 in 2-year steps. We will study the evolution of the number of calls per port, but also the transport capacity offered at each call. We will also examine the evolution of the maritime network of container ships in the Baltic Sea in 2012 and 2020.

We will base our analysis on the main Baltic Sea ports according to their container traffic in 2020 (Fig. 2). We have thus retained the ports that had a traffic of more than 50 000 TEU in 2020, i.e. 23 ports. It should be noted that, due to a problem of access to reliable data on calls in the port of Aalborg, the latter could not be taken into account for this study.

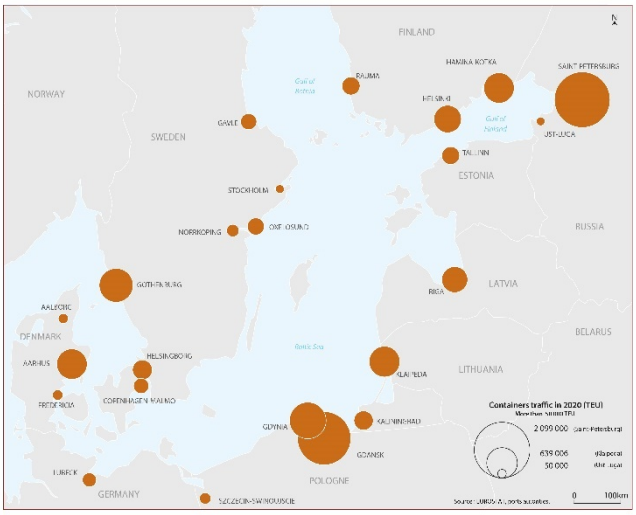

Figure 2. Containers traffic in Baltic Sea Port in 2020. Production: Ronan Kerbiriou, February 2023.

3 DATA AND METHOD

This work is based on the exploitation of maritime data from IHS (https://maritime.ihs.com/). IHS belongs to Lloyd's, which insures more than 80% of the world's merchant ships. Through this platform and via a subscription, it is possible to access data on ships with all their identification information and technical characteristics. We have built up our ship database using information from IHS.

IHS also offers another module on ship movements based on AIS signals. It is thus possible to download data on port calls according to a predefined list of ships, during a given period and by selecting a particular country or port. AIS is an on-board positioning system used to provide information to nearby vessels and to monitor the traffic situation. This tool complements maritime radar as a collision avoidance device, thus enhancing the safety and security of maritime navigation. Regulated by the IMO (International Maritime Organization) SOLAS Convention, the AIS system is mandatory on all ships over 300 gross tons, which concerns almost all commercial ships. The AIS can be diverted from its original purpose and used for other research purposes and represents a source of new information for scientific research [2]. Indeed, AIS messages contain a great deal of information that can be used to identify and locate the vessel. The analysis of the data transmitted by the AIS allows the study of maritime traffic and port passage. In this paper, these data on ships and their calls are the primary sources of

information that we will use to study the structural changes of container ships and the impact on containerised maritime traffic in the Baltic Sea.

The data downloaded from IHS needs to be prepared in order to be usable. To do this, we need to clean up the database to remove duplicate calls, harmonise the names of the ports (sometimes the call is indicated in the name of the terminal for example), remove information when the ship is in the anchorage area, etc.

4 RESULTS

In this part of the results, we will compare the ports of call in the defined ports (see part 2) by analysing the years 2012, 2014, 2016, 2018 and 2020 in order to have an evolutionary analysis over time. We will analyse the data in general terms before proposing an entry by ports. To conclude this part on the results, we will compare the evolution of the maritime network between 2012 and 2020 using graph analysis tools.

4.1 *Overall approach*

The anticipated effect of cascading in a maritime area such as the Baltic Sea is to see a general increase in the average size of container ships calling. Indeed, as previously specified, operators, under the effect of the acquisition of new vessels with increasingly large unit transport capacities, have repositioned larger vessels on secondary maritime spaces. We have therefore first observed the evolution of the average size of container ships calling at the ports studied and the number of calls (Fig. 2). A regular increase in the average size of container ships can be observed. The average size of container ships has increased from 1342 TEU in 2012 to 1903 TEU in 2020, i.e. an increase of 42%. At the same time, the total number of calls has decreased from 9988 in 2012 to 8276 in 2020, i.e. a decrease of 17%.

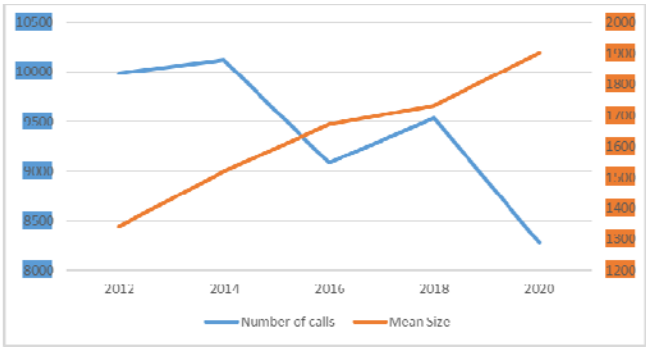

Figure 2. Evolution of the number of calls and the average size of container ships calling from 2012 to 2020. Source: IHS maritime.

The first observed impact of the construction and commissioning of the giant ships is a significant increase in the size of container ships calling at Baltic Sea ports. On average, larger ships are calling, but there are fewer of them. The trend is therefore towards a contraction and concentration of the transport offer on larger vessels. In Figure 3 below, it can be seen that the capacity offered at ports of call has also increased, driven by the increase in the average size of container ships. There was a significant jump between 2012 and 2014 before a slight decline and a further jump in 2020. The capacity offered at port exceeded 15.5 million TEUs, an increase of 17.5% compared with 2012.

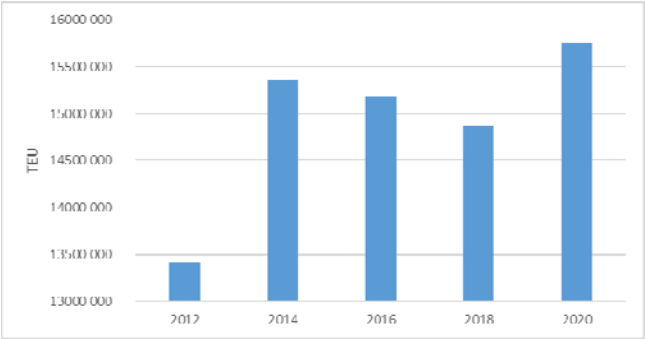

Figure 3. Evolution of the transport capacity offered by container ships in port from 2012 to 2020. Source: IHS maritime.

At the international level, the major shipping companies, in order to respond to the increase in trade in manufactured products, have had to expand their transport services. From the 1990s onwards, they moved into new maritime areas, competing with local operators. Smaller companies were absorbed in order to recover their markets [3]. From the 2010s onwards, mergers (the Chinese COSCO and China Shipping merged in 2016 and the Japanese NYK, K-Line and MOL merged in 2017 to become ONE) and large-scale acquisitions (CMA-CGM's takeover of NOL in 2015, Hapag-Lloyd's takeover of CSAV in 2014 and NILE-DUTCH in 2021, etc.) have taken place [4]. The number of shipping companies operating across the various seas of the world has thus contracted and the transport offer is concentrated with a smaller number. For the Baltic Sea area (Fig. 4), it can be seen that the number of shipping operators has also contracted as a result of various mergers and acquisitions. The number of container ship operators has fallen from 94 in 2012 to 69 in 2020, with a low point of 57 in 2018.

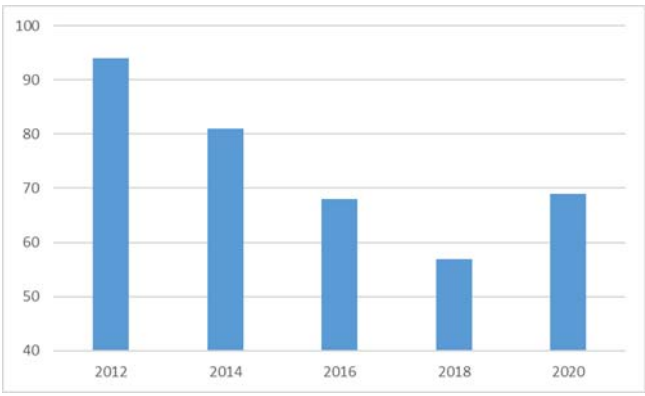

Figure 4. Evolution of the number of shipping companies operating in the Baltic Sea from 2012 to 2020. Source: IHS maritime.

On the other hand, the composition of the top three shipping companies in terms of unit transport capacity offered at ports of call has not changed. The same three operators can be identified in the different

years studied: Maersk, Unifeeder and MSC and their relative weight remains similar. In 2012, they accounted for 47% of the capacity transported, compared with 50% in 2020. It is essentially small operators, which offered a small number of calls, which have disappeared (mainly less than 20 calls in 2012). The reasons for the disappearance of certain operators are either economic bankruptcy and the closure of the company, or absorption or merger with another company and therefore the company no longer exists under the same name, or because the company has stopped serving the maritime area.

The regular decrease in the number of calls since 2012 in Baltic Sea ports is thus explained by the disappearance of small operators that offered shipping services with generally low-capacity vessels. The main shipping lines serving the Baltic Sea have maintained the number of calls during the period under review, but they have mainly increased the average size of container ships calling. The effects of cascading in recent years are therefore evident for the ports and maritime space of the Baltic Sea. We have been able to observe changes in the structure of container ships calling in this maritime area. After this global approach, we will continue the analysis with an approach at port level. Have all ports been equally affected by the effects of cascading? Are there winning and losing ports? In the next part of our analysis of the results, we will therefore compare the capacities offered in calls and the number of calls in the different ports studied and the evolution over the same study period.

4.2 *Analysis of port passage*

Generally, comparisons between ports are based on traffic statistics published mainly by the port authorities. The use of data on maritime calls linked to a database on ships makes it possible to extract new indicators that enable ports to be put into perspective with each other. In order to study the effects of cascading on the various Baltic Sea ports, we will therefore study the evolution of the number of calls, the capacity offered in calls and the average size of container ships between 2012 and 2020.

In the first part of the analysis of the results, it was observed that the average size of container ships calling increased overall, but that the number of calls decreased. At port level, the average size has increased in all the ports studied (+60% in Gdansk, +47% in Goteborg, +32% in Aarhus, +82% in Rauma, etc.). However, there are disparities between the different ports (Fig. 5). For example, in 2020, in Gdansk, container ships calling had an average unit transport capacity of 4846 TEU, far ahead of the port of Goteborg (3090 TEU) or Saint Petersburg (1860 TEU). The average size of container ships calling is highest in the ports of Gdansk, Goteborg and Aarhus and the further east one goes the smaller the average size becomes (less than 2000 TEU in Riga, Tallinn, Klaipeda, St. Petersburg, etc.). It can be observed that in the three identified ports, vessels with a unit transport capacity of more than 20 000 TEU reached the port in 2020. In the other ports, the largest container ships calling are smaller than 10 000 TEU (8241 TEU in Gdynia, 5711 TEU in Klaipeda, ...). The giants of the seas are therefore coming to Baltic Sea ports, thus interconnecting this area with the main world maritime trades. These ports therefore seem to be part of these maritime services, making the Baltic Sea an important maritime area and not only affected by transhipment. The ports of Gdansk, Goteborg and Aarhus can thus themselves be transhipment ports for other Baltic Sea ports.

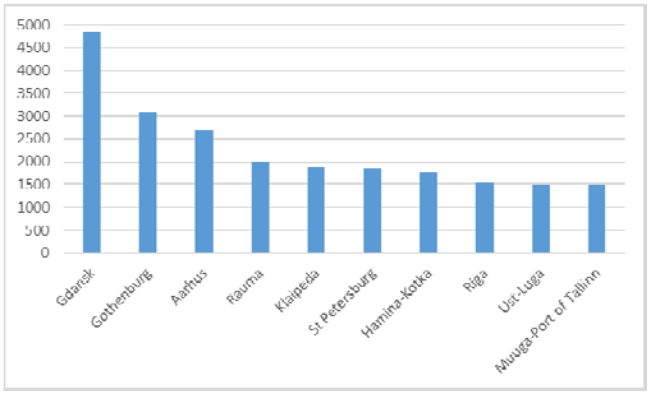

Figure 5. Average unit transport capacity in 2020. Source: IHS maritime.

Between 2012 and 2020, the number of calls decreased in all ports except for the Polish ports of Gdansk and Gdynia and the Swedish port of Helsingborg (Fig.6). The following graph shows the evolution of the ranking of the top 10 Baltic Sea ports according to the number of container ship calls. The port of St. Petersburg is the one with the most calls in all the years studied. The port of Gdansk, until 2016, was 10th in terms of number of calls, and from 2018 onwards it is ranked 5th in 2020.

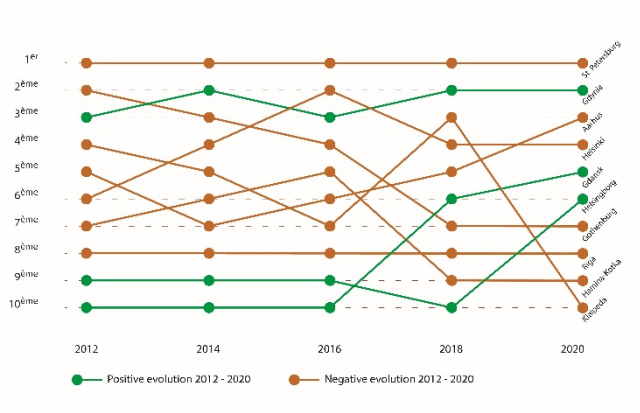

Figure 6. Top 10 Baltic Sea ports by number of calls from 2012 to 2020. Source: IHS maritime.

If the same analysis is carried out using the unit transport capacity offered in calls, the majority of ports have experienced a positive evolution between 2012 and 2020 (Fig. 7). In the graph below, we can observe the evolution in the ranking of the port of Gdansk, which has been ranked number 1 since 2018, when its number of calls also increased. On the contrary, the ports of St. Petersburg and Gothenburg, which are two ports with significant container traffic, have seen a decrease in the number of calls and the capacity offered in calls (-27% for Gothenburg and -5% for St. Petersburg). The two Polish ports in this top 10 are those which have seen the strongest growth in the capacity offered in calls (+123% for Gdansk and

+63% for Gdynia). As a reminder, the increase in capacity for all the ports studied was +17%.

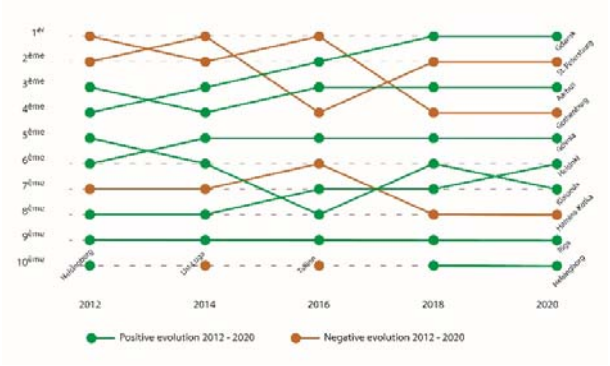

Figure 7. Top 10 Baltic Sea ports by unit transport capacity from 2012 to 2020. Source: IHS maritime.

The weight of the top 3 or the top 5 changes very little over the period. The top 3 over the various years account for around 40% of capacity and the top 5 for around 57%. Between 2012 and 2020, there has been a rebalancing of the distribution of capacities offered at ports of call (Fig. 8). The port of Gdansk accounted for 10% of capacity in 2012 and 18% in 2020. In contrast, the ports of Goteborg (15% in 2012 and 9% in 2020) and St Petersburg (15% in 2012 and 12% in 2020) concentrate a smaller share of capacity.

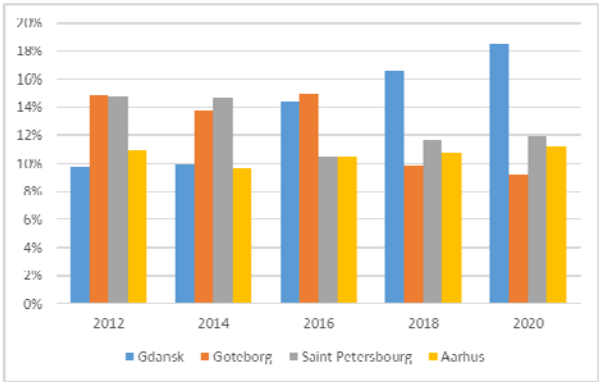

Figure 8. Relative weight in offered capacity of the 4 main ports. Source: IHS maritime.

These analyses make it possible to highlight the growing importance of the Polish ports, and more particularly Gdansk, in the containerised maritime networks. The latter has seen a significant development of its transport offer in recent years, to the detriment of the ports of Goteborg and St Petersburg. The port of Gdansk seems to be establishing itself as the strongest port in the Baltic Sea and as a regional hub. It should also be noted that the smaller ports have also seen an increase in the capacity offered in calls. Between 2012 and 2020, the situation seems to change from three main ports (Goteborg, St. Petersburg and Gdansk) to one main port (Gdansk), two ports that become more secondary (Goteborg and St. Petersburg) with smaller ports. To confirm this assumption, we will analyse the containerised maritime networks in 2012 and 2020 between the Baltic Sea ports and directly interconnected with the external ports. This network analysis using tools from graph theory will allow to assess the evolution of the strategic positions of the studied ports.

4.3 *Evolution of the maritime container network from 2012 to 2020*

Based on data from container ship port calls, it is possible to reconstruct inter-port connections and consequently maritime networks. In order to study the maritime networks of container ships interconnected with the Baltic Sea, we will rely on representations derived from graph theory. "Graph theory constitutes a mathematical framework that makes it possible to tackle problems in a very vast field. In the domains of geography, urban development and spatial planning, graph theory is used to tackle questions arising in the field of networks" [5]. In our case, graph theory is used to study the maritime networks of container ships and thus highlight the network structure within the Baltic Sea. Several methods exist to simplify a graph with the objective of removing certain vertices or links in order to make it readable. The different methods have been summarised and described in French by César Ducruet [6]. We have chosen the dominant flow method, which is related to the nodal region method [7]. This method has the advantage of being simple to use and easy to understand for an uninformed reader. The principle of this method is to define a threshold and to keep only the relationships above it. The graphs thus represent only partial information of the overall maritime network but allow the deep structure of the network studied to be brought out. The R software and the "i graph" package, which are freely available, were used to produce the graphs constructed from the incidence matrices at the vertices.

These traffic flows were selected by retaining only direct inter-port links, i.e. non-stop links, whose total capacity carried between two calls by all ships, once aggregated, remained above the threshold of 150 000 TEU carried. We have selected direct connections between the ports in our study and also with extra-baltic ports. We will compare the maritime container ship networks for the years 2012 and 2020 with the aim of analysing its evolution and deducing the impact of the structural evolution of container ships and cascading.

The Baltic Sea container ship network has expanded between 2012 and 2020 with the development of connections to external ports. In 2012, inter-port connections were concentrated around three external ports (Bremerhaven, Rotterdam, and Hamburg) compared to seven in 2020. New important maritime connections are emerging, particularly towards the port of Wilhelmshaven or from the port of Zeebrugge. On the other hand, between the Baltic Sea ports, the unit transport capacities offered are relatively low. The maritime connections with external ports are made with large capacity ships, while internal connections are not. Thus, the port of Gdansk is emerging as the main regional hub that interconnects with external ports (Bremerhaven, Zeebrugge, Felixstowe and Wilhelmshaven). In 2012, the port of Gothenburg was the main port at the heart of the Baltic Sea maritime network. Its position, although still important, has been overtaken by the port of Gdansk. The port of St. Petersburg has also experienced a decline in importance. In 2020, the capacities exchanged with external ports are less

important than in 2012 for the latter. These relations with the port of Rotterdam are still high in 2020, but those with the ports of Hamburg and Bremerhaven have decreased significantly. However, as a result of the economic sanctions imposed on the Russian Federation by the European Union, among others, as a response to the war in Ukraine, container traffic for the port of St. Petersburg has been strongly impacted [8]. The aim of the economic sanctions is to isolate Russia economically from international trade, which in turn affects the country's container traffic. The Baltic Sea is Russia's only western maritime access, which makes it a major access for its foreign trade [9]. The port of St. Petersburg is therefore likely to disappear completely from the maritime network as long as economic sanctions remain in place.

It is also important to note the position of the port of Hamburg in the 2012 and 2020 graphs. Its position as a regional hub has been marginalised with relatively low transport capacities exchanged to the benefit of the neighbouring port of Bremerhaven in particular.

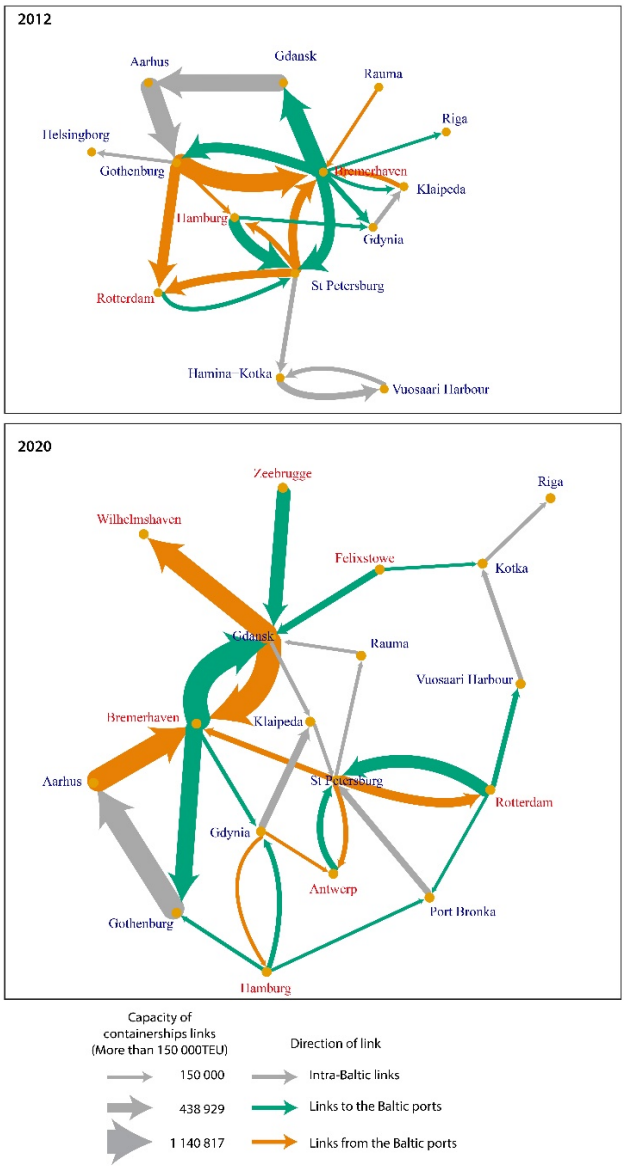

Figure 9. Sagittal representations of the graphs associated with containerized maritime traffic in 2012 and 2020. Source: IHS maritime.

In terms of unit transport capacities exchanged, the maritime network of container ships within the Baltic Sea and connected to the outside has evolved between 2012 and 2020. The port of Gdansk has established itself as the major regional hub in the Baltic Sea, with connections to the port of Bremerhaven in particular. The unit transport capacity between the two ports is over 1.1 million TEU in 2020 in each direction. This link is structured by the operators of the 2M alliance, primarily Maersk and MSC. With the recent joint announcement by the two operators of the end of their maritime alliance by 2024, it will be interesting, as a follow-up to this paper, to study the possible impact on this inter-port relationship.

5 CONCLUSION

The economic and especially industrial development of East Asia, driven by China, has placed this geographical area at the centre of world trade in goods, particularly for containerised flows, forcing the major shipping lines to adapt their offers. This reorganisation has offered new development prospects for containerised maritime transport with the construction of new container ships which can be described as giants of the seas and which have been put into service mainly on the Asia-Europe trade and also between Asia and North America. This structural development has led to cascading and has had an effect on the whole of the world's maritime areas and in particular on the Baltic Sea and its container ports. The objective of this paper has therefore been to assess the impact over time of the effects of cascading on the Baltic Sea ports and maritime network. The main conclusions that can be drawn from our analysis of the structural evolution of container ships and thus of cascading are

- The average size of ships calling has increased and at the same time the number of calls has decreased, concentrating and contracting the transport offer on larger ships;
- Many small shipping companies have disappeared from the Baltic Sea port landscape, concentrating the transport offer around a smaller number of operators (27% decrease);
- Emergence of the port of Gdansk (increase in the number of calls, average size of container ships, etc.) as a new regional hub;
- Development of the maritime network and interport relations with external ports and with the port of Gdansk as a relay;
- The strategic position of the ports of Goteborg and St. Petersburg is declining and becoming more secondary;
- The port of Bremerhaven is positioning itself as the main port hub between the main world trades and the Baltic Sea ports and at the same time the position of the port of Hamburg has been marginalised.

The development of container ship fleets and the resulting cascading has had a significant impact on maritime traffic and port passage in the Baltic Sea. The maritime networks have been restructured around a strong link between Bremerhaven and Gdansk under the main impetus of the operators of

the 2M alliance (Maersk and MSC). This work deserves to be continued over time to confirm the previous conclusions but also to assess the impact of the end of the 2M alliance by 2024. Continued analysis will also make it possible to study the impact of the war in Ukraine and the economic sanctions against the Russian Federation on its maritime traffic in the region and on the general structure of the maritime network of container ships in the Baltic Sea.

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