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Recent Patterns of Competition and Co-operation among Major Container Ports in Asia: An Implication for Busan

Satya Sahoo* · Dong-Wook Song**

ABSTRACT

Seaports are crucial for regional development as they offer an employment to adjacent societies through industrialisation and value-added services. Since Asia has become a manufacturing hub for the world economy with a large volume of exports and imports, this paper investigates the trading pattern of container line services for three major ports in Asia: that is, Shanghai, Singapore and Busan. Ports compete and co-operate with neighbouring ports in the region to generate the greater throughputs and subsequently create economic values. Utilising the liner services data from AXS Marine's Alphaliner database, this study proposes an inter-dependency ratio of container ports in a way to understand the degree of co-operation among the ports from a foreland perspective. The findings suggest that, the Singaporean port generates around 40% of its volume without depending on Shanghai and Busan, while the Busan port relies about 90% on Shanghai and Singapore to generate its volume. The Port of Busan is desperately needed to diversify the liner services/routes portfolio and expand its self-dependency to become a transshipment hub located in the Far East. This paper concludes by identifying several challenges and opportunities for the Port of Busan as a specified example. Big data in maritime industry could provide a platform for decision support systems to port operators, managers and policy-makers so as to uncover the market's gaps and needs, thus increasing port market shares and retaining the greater container throughputs.

Key words : competition, co-operation, container ports, Asia, Busan

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1. Introduction

Seaports serve as a gateway to international trade, integrating a region into the world, which is crucial for the region's economic growth (Chang et al., 2014; Del Mar Cerban et al., 2011; Goss, 1990; Haynes et al., 1997; Shan et al., 2014). As ocean transportation comprises 80% of the international trade of commodities, the seaports (hereafter referred to as ports) hold two primary responsibilities: (i) connecting the seaborne transportation to hinterland connectivity and (ii) improving the regional economy (Jung, 2011; Park and Seo, 2016). Port facilitates exports and imports of raw materials and containerised products, indirectly enhancing the regional economy. It also provides value-added services and employment in the region, directly boosting the local economy. Hence ports need to be strategically built and operated to support the country's economy.

The growth of globalisation has led to a shift in production centres. Asia has become the manufacturing hub, serving the needs of the world. Hence we observe significant growth of container ports in the Asian region. Nine out of the top ten container ports in terms of annual container throughput are from the Asian region (Lloyd's List, 2021). However, most of these large ports are located in China. Seven out of the top ten container ports are from China, while only Singapore and Korea's Busan port are the only two ports from other Asian countries in the top ten global container ports. The surge in the throughputs of Chinese ports creates intensive competition for the neighbouring ports.

Asia is the container trading hub of the world, with almost half of the world's container ships deployed to provide liner services connecting the region to the world. The port and maritime trade related data were not readily available in the past. So, several strategic decisions for ports were not entirely scientific and somewhat depended on qualitative information. Due to the development of digitalisation and availability of maritime and ports related data, this study aims to investigate the trade patterns for top ports in three major Asia economies – China's Shanghai port, Singapore port and Korea's Busan port. Secondly, this study aims to operationalise the conceptual framework of Song (2003) on port co-opetition with empirical data to observe the competitive and co-operative strategies between the mentioned three major Asian ports. Finally, as there exists intense competition between Chinese and non-Chinese ports in the Asian region, this study observes the challenges and opportunities for Busan port as a strategic direction for non-Chinese port perspective in the region.

The remaining section of the study is presented as follows: Section 2 provides an overview of container trade in Asia. The method and dataset used for the analysis are presented in section 3. Section 4 presents findings of competition and co-operation for major Asian ports. The challenges and opportunities for Port of Busan are presented in section 5. This section also provides some qualitative recommendations from the findings to improve the market share for Busan port. Finally, section 6 provides the concluding remark of the study.

2. Trade Patterns in Asia

Asia is the industrial centre of the world where over 50% of the world export and import of goods and commodities by value take place from or to Asian countries. In 2019, Asia's total export and import of \$7.24T and \$7.69T, respectively (Source: Exportgenius), while the world export and import were around \$18.00T (Source: OEC World). Amongst Asian countries, that serves as the major exporting nation. During the last three decades, the exports of China have increased by \$2.56T from \$84.94B in 1992 to \$2.65T in 2020. The most recent exports are led by broadcasting equipment, computers, semiconductors, and machinery. China mainly exports to the United States, Japan, Germany, and Korea. As China is a substantial industrial country, it imports raw materials and equipment such as crude oil, iron ore, soybeans, automobile equipment, and integrated circuits from Japan, Korea, the United States and Germany.

Since this study aims to compare competitive and co-operative strategies between three major Asian ports: Shanghai, Singapore, and Busan port, this section concentrates on the economic and trade activities of the corresponding countries as a basis for port operations (Park and Medda, 2018). Unlike China, Singapore is a smaller country with a GDP of only \$340B as of 2020; however, the strategic location could be regarded as one of the main factors for Singapore to be a key player in international trade. In 2020, Singapore had an export and import of \$281B and \$301B, respectively, which sums to be greater than the country's economy. It primarily trades with crude oil, refined petroleum products, precious metals, medicinal products, electronics and machinery with China, the United States, Malaysia, Indonesia and Japan.

The economy of Korea is different as compared to that of China and Singapore. The per capita GDP of Korea is three times that of China. Hence labour cost in Korea is greater than that of China. Further, unlike Singapore, Korea does not have a very high value of trade vis-à-vis its large economy. In 2020, Korea exported a total of \$531B compared to \$446B of imports. However, the country's trade surplus has decreased from \$116B in 2015 to only \$95B in the year 2020. Korea primarily exports electronics, automobiles, and cargo and passenger ships while importing crude oil and energy products. This could be mainly due to the development of electronic companies such as Samsung and automobile and heavy industries such as Hyundai. The details of the top 10 exporting and importing countries for China, Singapore, and Korea is presented in Table 1.

As the maritime industry enables over 80% of the world trade demand, the ports play a crucial role in facilitating the export and import of goods and commodities in Asia, boosting the regional economies. The throughput data of the top 10 container ports in the world are presented in Table 2. It is interesting to observe that 9 out of the top 10 container ports are solely located in three Asia countries: China, Singapore, and Korea. It can also be seen in Figure 1 that the throughput of

Table 1. Top 10 trading partners of China, Singapore, and Korea (as of 2020)

Exports by value						
	China		Singapore		Korea	
Rank	Partner countries	Value of trade	Partner countries	Value of trade	Partner countries	Value of trade
1	United States	437.76	China	84.61	China	162.39
2	Japan	151.39	United States	27.62	United States	74.97
3	Germany	112.19	Malaysia	22.87	Vietnam	48.01
4	Korea	109.51	Indonesia	14.76	Hong Kong	30.93
5	Vietnam	103.66	India	11.29	Japan	25.06
6	United Kingdom	73.12	Japan	11.03	India	12.08
7	Netherlands	64.88	Korea	9.66	Malaysia	11.58
8	India	64.25	Thailand	9.32	Singapore	11.03
9	Mexico	59.77	Vietnam	8.24	Mexico	10.65
10	Australia	57.21	Netherlands	6.57	Germany	10.63
Imports by value						
	China		Singapore		Korea	
Rank	Partner countries	Value of trade	Partner countries	Value of trade	Partner countries	Value of trade
1	Japan	132.55	China	78.86	China	125.67
2	Korea	131.46	Malaysia	36.45	United States	53.43
3	United States	122.36	United States	25.88	Japan	42.90
4	Germany	106.18	Japan	15.77	Germany	20.03
5	Australia	101.82	Indonesia	12.55	Vietnam	19.63
6	Brazil	67.94	Korea	11.03	Australia	17.16
7	Vietnam	49.44	Thailand	10.61	Saudi Arabia	14.42
8	Russia	49.29	France	8.31	Russia	12.52
9	Singapore	42.90	India	7.23	Singapore	9.66
10	Malaysia	38.73	Australia	7.10	Malaysia	8.63

Note: Value of exports and imports is in 2020, denoted in Billion USD.

Source: OEC World (2022), <https://oec.world/>

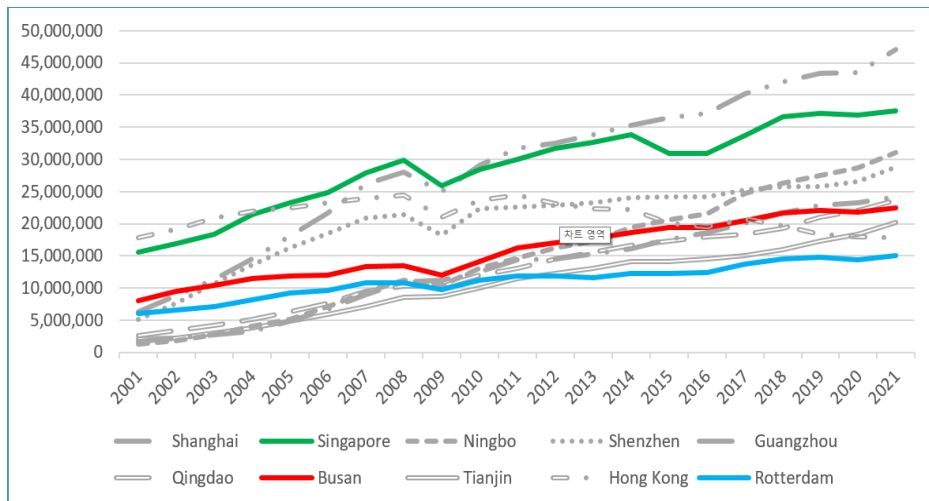
Asian ports has increased significantly over two decades. For example, the Port of Ningbo and Guangzhou had only a throughput of 1.2 and 1.6 million TEUs respectively in 2001, which ascended to over 31 and 24 million TEUs volume by 2021. At the same time, there are other Asian ports, such as Hong Kong, that did not grow by cargo handling volumes. This might be a result of an internal decision of the Government of China; however, other neighbouring countries with large ports, such as Singapore and Korea, need to develop strategies for remaining competitive and attracting volumes to their ports.

Table 2. List of top 10 container ports by throughput in 2021

Rank	Port	Country	Re- gion	2021 annual throughput (TEU)	2020 annual throughput (TEU)	Annual percent change(%)
1	Shanghai	China	Asia	47,030,000	43,501,400	8.11
2	Singapore	China	Asia	37,546,368	36,870,940	1.83
3	Ningbo	China	Asia	31,080,000	28,734,300	8.16
4	Shenzhen	China	Asia	28,760,000	26,553,000	8.31
5	Guangzhou	China	Asia	24,180,000	23,191,500	4.26
6	Qingdao	China	Asia	23,700,000	22,004,700	7.70
7	Busan	China	Asia	22,498,759	21,813,073	3.14
8	Tianjin	China	Asia	20,260,000	18,356,100	10.37
9	Hong Kong	China	Asia	17,854,000	17,952,000	-0.55
10	Rotterdam	The Netherlands	Europe	15,000,000	14,349,446	4.53

Note: Value of exports and imports is in 2020, denoted in Billion USD.
Source: Clarksons Research (2022).

Figure 1. Annual container throughput for top 10 container ports.



Notes: The line graph presents the growth of the top 10 container ports in 2021.
The chart highlights the rapid growth of Chinese ports vis-à-vis non-Chinese ports.

3. Competition and Co-operation from An Asian Ports Perspective

The competition and co-operation within regional ports are well investigated in the literature (Luo et al., 2022). Ports compete with other regional ports at different levels to increase their market share (Slack, 1985) and satisfy the growing demand (Verhoeff, 1981). Inter- and intra-port competition between port operations for acquiring hinterland shipment and transshipment as a non-cooperative strategy is investigated in Song et al. (2016). On the other side, ports handling similar or even different types of cargo can develop co-operative strategies to serve their customer better and improve management. A practice of port co-operation, integrating vertical and horizontal chains of transportation in Asian and European contexts, is presented in Ryoo (2011) and Stamatović et al. (2018).

Song (2002) examines the competition and co-operation existed between the container ports in Hong Kong and South China from a strategic point of view. In the early 1990s, Hong Kong was the largest container port in the world, but after 1997, when its sovereignty was handed to China, it faced steep competition from neighbouring Chinese ports, notably Shenzhen and Guangzhou. The impact of such competitive strategies is now observed with the continuous decline of the container throughput for Hong Kong and the growth of the adjacent ports in South China. Using a game theory approach Wang et al. (2012) identifies several factors such as regional port governance for supporting co-operation and alliance formation to attract container volumes from contestable hinterlands. It also helps to develop an efficient logistics hub with a fully integrated transport ecosystem. Anderson et al. (2008) also extended the study of port competition from a game-theoretical perspective to understand how competitor ports respond when a neighbourhood port grows faster to become the regional container hub port. It also presents whether and how the growing port captures and defends market share by building additional infrastructure. The study also investigates the game theory framework using a case study between Busan and Shanghai ports. Hence, port co-operation and integration, in general, are also advantageous transportation from a business and social perspective (Álvarez-SanJaime et al., 2015).

Though the concept of competition and co-operation between ports is extensively investigated, there are only centres around quantifying the degree of competition and co-operation between ports. Asgari et al. (2013) is one of the few articles which empirically investigates the competition and co-operation between two major hub ports in Asia (Singapore and Hong Kong) using scenario analysis. Furthermore, studies limit competitive and co-operative strategies for ports only to hinterland market. This study aims to provide a simple empirical analysis to understand the port dependency on neighbouring ports in the region from the foreland perspective. But doing so, the study also helps to understand the trading pattern of

container services for major ports in Asia using liner services data that can enhance the management decision making for ports, container lines, and even regional governments (Sena et al., 2019; Tan et al., 2017). The development of technology facilitates this aspect by digitising operations, storing colossal information, and processing useful findings almost instantaneously. The live and historical positions of ships are tracked through automated identification system (AIS), stored and processed through various cloud platforms. Technology has also become cheaper and more predominant over time. Hence, observing the trading pattern of container liner services to understand the dependency of ports on other ports in the region is possible.

Container shipping is a form of liner service with fixed routes and port calls at the scheduled time. Since the container line services do not receive all the loading and discharging container boxes from a single port in the region, they rely on several ports to attract large volumes. For example, for the liner services between Far-East and North-Europe route, the boxes are typically loaded in Asian ports and unloaded in European ports as most of the finished products carried in the boxes are manufactured in Asia due to low labour cost and well-established production ecosystem, and consumed in Europe as it has higher per capita GDP. If we observe the loading centre for this service route, not all the containers are loaded from China. There are other major manufacturing countries like Indonesia, Malaysia, Vietnam, Thailand, Bangladesh and India, amongst others, who either provide cargo volume to the Europe-Asia route directly or through transshipment ports such as Singapore and Busan.

Moreover, multiple mega ports within China produce their cargo volumes and attract liner services. From a liner service provider perspective, since it is not possible to get the entire volume of cargo from a single port, it is ineffective to call only one port in the region instead of a loop of ports that meets its container volume requirement. Hence regional/adjacent container ports need to co-operate with other ports to attract container liner services. Additionally, ports strategically develop value-added services complementing the adjacent ports and establish a logistics ecosystem. Similar co-operation strategies are also designed for the regional ports at the discharge area, for European ports in this example.

To understand the intra-dependency of the ports, it is essential as well to assess the trading pattern (export and import) of commodities for the corresponding countries. It is observed that Korea majorly trades with China, USA and Japan, as presented in Table 1 earlier in the text. It also has other Asian and European countries as strong trade partners. Similar to Korea, China and the USA are the leading trade partners for Singapore. Singapore also presents a good trade relationship with other Asian countries, mainly from the South Asian region. The volume of goods/commodities exported to and imported from China is significantly higher than that of Korea and Singapore. Unlike the two countries that have China as the major trade partner, the USA is the major trading country for China. China also has a strong trade relationship with the Far East countries (including Japan and Korea),

South Asian countries such as Vietnam and Malaysia, and Europe. The differences in import and export of commodities create the balance of trade for any country and establish dependency on each other. This dependency of countries on each other for trade creates resilience to find another trading partner, which is reflected in their corresponding trading ports creating co-operation and intra-dependency between ports.

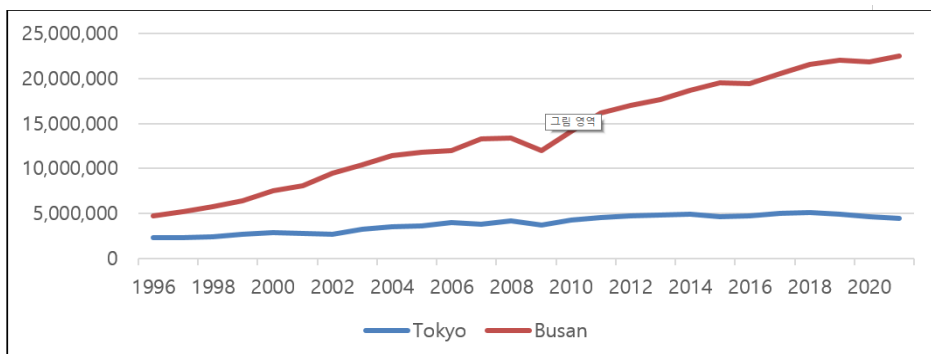
4. Method and Data Issue

Regional ports compete and co-operate to get a larger volume of cargo. Usually, this competition for cargo volume is for transshipment containers and not for hinterland containers since port generating their hinterland volumes have fewer options to share with other regional ports. Transshipment containers increase the throughput volatility of a port (Notteboom et al., 2019) due to the fact that a calling-port decision is made by shipping companies; hence things become risky for the ports. Ports with higher transshipment volumes compete with the adjacent ports in retaining and increasing their volume, which otherwise can significantly reduce their throughput volume, leaving them out of the mainline routes.

As shown in Figure 2, Tokyo had an annual throughput of 2.3 Million TEUs, and Busan had a yearly throughput of 4.7 Million TEUs in 1996. However, in 2021, Tokyo's throughput only raised to 4.5 Million TEUs while Busan generated a volume of 22.5 Million TEUs. Thus, Tokyo was receiving around half of the volume of Busan, which has dropped to 1/4th in 25 years. Even though both the ports are located in the same region, by attracting large volumes of transshipment containers, the Port of Busan has emerged as the leading port in Far East Asia.

As regional ports co-operate for existence and compete to scale up their size, they need to develop a strategy to tradeoff between the competitive and co-

Figure 2. Annual container throughput for Port of Tokyo vs Port of Busan.



Source: Clarksons Research (2022).

operative for a win-win scenario between ports (Hales et al., 2016). Brandenburger and Nalebuff (1995) introduced the word co-opetition, referring to a game theory strategy where players co-operate and compete. This is also in line with the context of port co-opetition concept proposed by Song (2003). Though port co-operation is essential, there are only limited studies empirically evaluating the degree of co-operation or dependency between ports. This study attempts to present the port intra-dependency ratio from the foreland perspective to quantify the dependence of a port with adjacent/reference ports as follows:

$$R_i^{\Sigma j} = \frac{TEU_{\Sigma j}}{TEU_i} \quad (1)$$

Where, $R_i^{\Sigma j}$ represents the port intra-dependency ratio of port i on the adjacent/reference port(s) j which are using the common liner services. Twenty-foot equivalent unit (TEU) indicates the average weekly 20-foot equivalent container capacity calling at the port.¹ The ratio ($R_i^{\Sigma j}$) estimates the percentage of the volume of cargo (in the form of TEU) which a port i depends on the reference port(s) j compared to its total volume. A higher (lower) $R_i^{\Sigma j}$ denotes higher (lower) dependency of port i on reference port(s) j . This port intra-dependency ratio is an augmented form of port dependency ratio presented in DeSalvo (1994) and Won et al. (2006) which is derived from the demography and health economics literature (Loichinger et al., 2017; Muszyńska and Rau, 2012; Sinnathurai, 2013).

4.1 Data and Description

AXSMarine's Alphaliner database is used to collect the data related to the container liner services and the vessels allocated for each service. Alphaliner combines individual vessels allocated for each container liner service with the ship's AIS to provide updated routes and port calls.²

Currently, there are 1,842 container liner services provided around the world through 6,136 container ships. There are 3,016 container vessels which are responsible for delivering 767 liner services connecting Asia to the world. The Port of Shanghai is connected with 374 container liner services with the help of 1,761

¹ Please note: TEU does not refer to the actual weekly container turnover volume (loaded and unloaded) of the port, rather the cumulative 20-foot equivalent container space in fully cellular ships calling the port on a weekly basis. The actual volume of container turnover is only available to the ports and terminals which is not shared with other. Further, as the study considers the ratio, rather than the absolute value, the cumulative volume of container space can reflect the dependence of ports.

² The container liner services for October 2020 is used; the results might be different at a different period of time.

Table 3. Comparison of container liner services: World vs Major Asian Ports

		World container trade	Busan	Singapore	Shanghai
	No. of services	1,842	261	334	374
	No. of vessels deployed	6,136	944	1,247	1,761
	Avg. TEUs capacity per week	3,600,134	925,332	1,340,815	1,525,531

Source: AXS Marine (2022).

container ships, making it the largest liner network globally. Singapore and Busan port have the most extensive network outside of China, with 334 and 261 weekly liner services, respectively. Container ships of a cumulative capacity of over 1.5 million TEUs call Shanghai every week, whereas Singapore and Busan receive 1.34 million and 925 thousand TEU capacity weekly. Table 3 provides the details of the number of services, vessels allocated, and weekly TEU capacity for the ports.

5. Competition and Co-operation among Major Asian Ports

The container liner services are operated in a close loop, where the liner services call multiple loading and unloading ports. A total of 261 container liner services with a cumulative capacity of 925,332 TEUs call Busan port every week, whereas Singapore and Shanghai receive a cumulative capacity of 1,340,815 and 1,525,531 TEU from 334 and 374 container liner services weekly. There exists 54 common container services between Busan, Singapore, and Shanghai port which provides a total of 457,859 TEU capacity weekly. There are eight liner services common between Busan and Shanghai exclusively³, while Shanghai shares a high number of common liner services (83 and 64 respectively) with both Busan and Singapore. Hence, Busan and Singapore have less dependency in terms of liner shipping volumes, while both the ports have a greater dependence on Shanghai for getting their volumes. There are only 116 liner services exclusively calling Busan (that is, not calling Singapore and Shanghai), generating a cumulative container capacity of 104,957 TEUs per week. This is lower than 1/9th of the weekly TEU

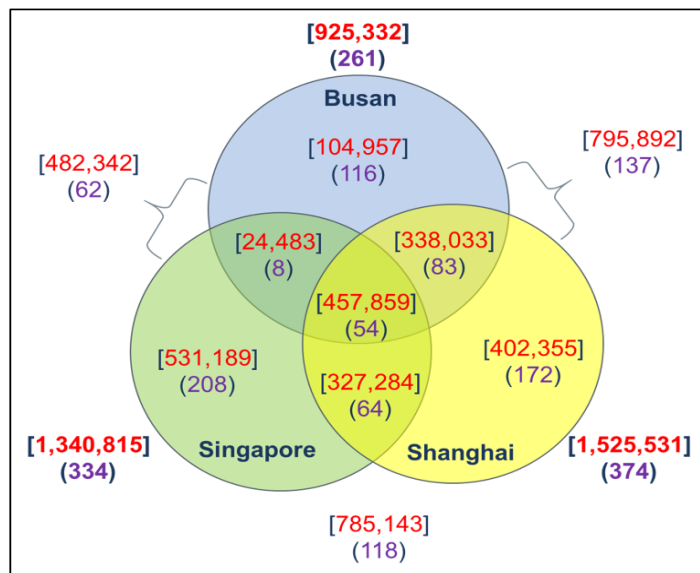
³ Exclusively here refers to the liner services which are only calling the aforementioned port(s) and not with other port(s).

capacity, indicating that, Busan heavily relies on Singapore and Shanghai for getting its cargo volume. On the other side, Singapore gets around 531,189 TEU capacity weekly from 208 liner services which do not call Busan and Shanghai, indicating that Singapore port can generate a higher cargo volume without depending on Singhai and Busan ports. Shanghai receives about 1/4th (402,355 out of 1,525,531) of its TEU capacity on its own. Shanghai has a large hinterland for which it can self generate higher cargo capacity without depending on the other two ports. In contrast, despite being a transshipment port, Singapore generates a higher TEU capacity without relying on adjacent ports (Busan and Shanghai), indicating a well-diversified liner services network. The container market share for Busan, Singapore, and Shanghai is presented using a diagram in Figure 3.

As observed in the Venn diagram, the entire container market share for Busan, Singapore, and Shanghai can be divided into three zones as follows:

- The Common liner services indicate the liner services that call Busan, Singapore, and Shanghai.
- Liner services for two ports only: This includes the liner services calling only two ports, that is, (i) Busan – Singapore, (ii) Busan – Shanghai, or (iii) Singapore – Shanghai.

Figure 3. Container liner market shares.



Notes: [figure] represents average TEUs capacity per week.
(figure) represents the number of services per week.

- Liner services only calling one port: Out of the three ports considered in the analysis, this includes the liner services calling only Busan, Singapore, or Shanghai.

Based on the three mentioned categories of liner services, the intra-port dependency ratio is evaluated and explained in the following section.

5.1 Common Liner Services for Busan, Singapore, and Shanghai

The port intra-dependency ratio ($R_i^{\sum j}$) for Busan port with respect to adjacent all three ports (port i is Busan while ports j are Busan, Singapore, and Shanghai) is 49.48%, indicating that Busan depends on Singapore and Shanghai ports for almost 50% of its volume. Similarly, the port intra-dependency ratio ($R_i^{\sum j}$) for Singapore and Shanghai ports are 34.15% and 30.01%, respectively, suggesting that Shanghai and Singapore still depend on other ports for generating their volumes, but to a lesser extent than Busan port.

North Europe – Mediterranean – the Far East is (Figure 4) the most popular common container liner route, which calls Singapore, Shanghai, and Busan. There are 20 container liner services in this route which calls the three ports generating an average cumulative capacity of 312,096 TEUs per week. North Europe – Mediterranean – the Far East is also the most container liner routes.

The second most popular liner trading route calling all three ports is the North America – Asia route (Figure 5), providing seven weekly container services with an average capacity of only 39,209 TEUs. Even though this route provides less cargo volume than the Europe – Asia route, this is an important trading route for Shanghai and Busan. The United States is the largest trading for China, with an export value of 453 Billion USD in 2020 (sources: UN Comtrade); and Busan is the largest port in the Far East region, making it the gateway between the two continents.

Figure 4. Container liner route: North Europe– Mediterranean – Far East.



Figure 5. Container liner route: North America – Asia.



5.2 Common Liner Services: Busan – Singapore (Exclusive)

Only six container liner services call Busan and Singapore which do not call Shanghai (Figure 6), implying Busan and Singapore do not have an extensive dependency on each other. This is reflected in the lower port intra-dependency ratio of only 2.65% and 1.83% for Busan and Singapore on the trade between the two ports, respectively. Since both the ports are transshipment ports, they compete for the generating volume in the region, limiting the exclusive trade between the two ports. Furthermore, the liner services exclusively between Singapore and Busan are limited within the Asian region. Only four liner services operate solely between Busan and Shanghai, providing a container capacity of 13,988 TEUs weekly. There are also two liner services connecting the Far East to the Indian subcontinent calling Busan and Singapore. Overall, it is observed that no long trading routes connecting Singapore and Busan exclusively. All the longer liner services connecting Singapore and Busan have Shanghai as a port call.

Figure 6. Container liner route: Intra Asia – NE Asia – SE Asia.



5.3 Common Liner Services: Busan – Shanghai (Exclusive)

Busan and Shanghai have a higher port dependency on each other, with a large number of common liner services between the two ports (Figure 7). The port intra-dependency ratio for Busan on Busan – Shanghai trade is 36.53%, while for Shanghai is 22.16%. This indicates that Busan depends on the common services between the two ports more than Shanghai. Two major liner service routes which call Busan and Shanghai (and not calling Singapore) include North America to Asia and Intra Asia to Oceania routes. There are 39 liner services between North America and Asia which exclusively calls Busan and Shanghai every week with a cumulative capacity of 259,793 TEUs.

Intra Asia to Ocean (Figure 8) is another major route calling the two ports, with 34 container services and an average of 58,951 TEU cumulative capacity every week. Small container vessels are allocated in this route, resulting in lower volume capacity. All the container routes between the Far East to Europe call Singapore; hence, there are no liner services on Europe – Asia route exclusively calling Busan and Shanghai.

Figure 7. Container liner route: North America – Asia.



Figure 8. Container liner route: Intra Asia – Oceania.



5.4 Common Liner Services: Singapore – Shanghai (Exclusive)

Though Singapore is a transshipment port and Shanghai (Figure 9) receives its major cargo from the vast Chinese hinterland, the port intra-dependency between Singapore and Shanghai is comparable. The intra-dependency ratio for Singapore is 24.41%, while for Shanghai is 21.45%. This indicates that though Singapore has a high volume of transshipment containers, it has a well-diversified source of cargo volume and does not depend on only Chinese cargo. There are 20 liner services in North Europe – the Mediterranean – the Far East, providing port call services to Singapore and Shanghai that do not call Busan port with a cumulative 165,766 TEU capacity weekly. This indicates that there are a large number of Europe to Asia trade that Busan port are not attracting.

Additionally, there are also 20 Intra-Asia container liner services which connect North-East Asia to South East Asia through Singapore and Shanghai (Figure 10). It suggests that there are opportunities for Busan to identify and develop strategic partnerships with these liner services to generate higher cargo volume.

Figure 9. Container liner route: Intra Asia.



Figure 10. Container liner route: North Europe – Mediterranean – Far East.



5.5 Liner Services: Exclusive to Busan

The port intra-dependency of Busan on itself is only 11.34% indicating that the Port of Busan depends extensively on cargo volume from Shanghai and Singapore (Figure 11). It also refers that Busan does not have a well-diversified liner route portfolio with a lower self-dependency ratio. Busan port has a low self-dependency ratio and is more serving for transshipment cargo, making it vulnerable since any risks, such as geopolitical, financial or even pandemic, that affect either Singapore or Shanghai will have a high impact on Busan's throughput. There are also no major liner routes that call Busan exclusively. It has a good liner network within Asia, providing 104 services exclusively to Busan with an average capacity of only 82,337 TEU weekly. It also suggests that through Busan has a good network of services within Asia, the port still has to improve its connectivity beyond Asia to compete with the adjacent ports.

5.6 Liner Services Exclusive to Singapore

Though Singapore is also a transshipment port like Busan it is able to generate a high volume of cargo on its own as its self-dependency ratio is as high as 39.62%. It also indicates that Singapore relies on Shanghai and Busan for almost 60% of the TEU capacity (sharing common liner services), and it can generate about 40% of the volume capacity from its exclusive liner services that do have Shanghai or Busan has port calls. The high self-dependency might be attributed due to two reasons: (i) the strategic location of Singapore, which makes it the hub of transshipment for not only South Asia but also links between Africa and Oceania; and (ii) even though there are other ports in Malaysia, Indonesia and Philippines location in the same region of Malacca Strait, due to improved operational efficiency, value-added services offered and well established strategic partners, Singapore is able to attract container liner.

Singapore is the central transshipment hub for Africa – Oceania and Intra –

Figure 11. Container liner route: Intra Asia.



Asia routes (Figure 12). There are 154 liner services in these routes providing a cumulative capacity of 321,194 TEUs per week. This provides a significant cargo volume to Singapore over the adjacent ports and helps in diversification and risk management.

There are also 16 liner services in the North America – Asia route (Figure 13), which exclusively calls Singapore (and does not call either Shanghai or Busan port) with a weekly TEU capacity of 64,864 units. Though it is a small trade volume, it is unique as it strategically connects South Asia and Africa to North America. Hence, Singapore stays futuristic, connecting the production and labour hub to consumer hub, and hedges itself for the US-China trade war, diversifying its risks.

5.7 Liner Services Exclusive to Shanghai

Contrary to Singapore and Busan (Figure 14), Singapore is not a transshipment port, rather services as a major exporting port for China servicing its colossal hinterland. This also helps Shanghai to create its own cargo volume rather than depending on adjacent ports. The self-dependency ratio for Shanghai is relatively stable at 26.37%. There are 134 container liner services which call Shanghai (and

Figure 12. Container liner route: Intra Asia – Africa – Oceania Services.



Figure 13. Container liner route: North America – Asia.



Figure 14. Container liner route: Intra Asia – Oceania Services.
(including domestic)



Figure 15. Container liner route: North America – Asia.



do not call Busan and Singapore) in Intra Asia and Oceania route (including domestic routes). These services provide a cumulatively 191,905 TEUs on a weekly basis. There are also 14 exclusive liner services between North America and Asia with a 95,258 TEU capacity weekly.

These exclusive North America liner services do not call Busan, even though it is located at the intersection of both continents. It also suggests a high volume of trade between North America and China (Figure 15) for which shipping lines can provide dedicated direct services.

5.8 Overview of the Port Intra-Dependency Ratio

Table 4 summarises the port intra-dependency ratio for all the scenarios explained earlier. The results suggest that, amongst the three ports, Singapore has the highest self-dependency ratio, followed by Shanghai, and Busan has the lowest self-dependency ratio. On the contrary, Busan has the highest port intra-dependency ratio on the common liners between Busan, Singapore, and Shanghai, indicating that Busan depends heavily on the co-operation between the three ports.

Table 4. Port intra-dependency ratio overview

Port intra-dependency ratio	Busan (%)	Singapore (%)	Shanghai (%)
Busan	11.34	–	–
Singapore	–	39.62	–
Shanghai	–	–	26.37
Busan – Singapore	2.65	1.83	–
Busan – Shanghai	36.53	–	22.16
Singapore – Shanghai	–	24.41	21.45
Busan – Singapore – Shanghai	49.48	34.15	30.01
Total	100.00	100.00	100.00
Variance of the dependency ratio	4.73	2.78	0.16

Comparing Busan and Singapore ports, as both serve higher transshipment volumes, it is observed that Busan has the highest dependency on Busan-Singapore-Shanghai liner services, followed by Busan-Shanghai liner services and then on itself. On the other hand, Singapore has the highest dependence on itself, followed by Busan-Singapore-Shanghai and Singapore-Shanghai liner services. This increased dependency on a few adjacent ports can increase the risks of Port of Busan, especially for the transshipment cargo volume. If Busan aims to become the transshipment hub in the Far East, it needs to reduce its dependency on Busan-Singapore-Shanghai services (say from 50% currently to less than 35% as that of Singapore) and needs to increase its self-dependency from about 11% currently to nearly 40% (similar to Singapore).

6. The Position of Busan Port within Asia: Challenges and Opportunities

After understanding the intra-dependency of three major ports in Asia, this section focuses on Busan port as a case study to present the recent development of the port and addresses several challenges and opportunities which could support port authority and policymakers to build a strategic partnership with other countries, organisations and liner companies. It will help Busan port in two ways: (i) to improve container throughput for increasing the port throughput, and (ii) to reduce the risks of transshipment volumes by diversifying the liner network connectivity for Busan port.

6.1 Busan Container Terminal Development

Busan port was started in 1876, with the container operations commencing

in the 1980s. Since the 1990s, the Busan port has been one of the top 10 largest container ports globally. The construction of Busan New Port started in 1995, and until 2020, six out of ten planned terminals are operational. Figure 16 shows the satellite image of the old and new terminals at Busan port. The highlighted section on the right side of the image indicates the old terminals, while the left side presents the new container terminals.

There are nine dedicated container terminals in the old Busan port; two midsize to Panamax container capacity, five terminals with Very Large Container Ships (VLCS) capacity, and two terminals capable of accommodating Ultra Large Container Ships (ULCS). The names of each terminal at the old Busan port are presented in Table 5. The old terminals do not have well-established railway connections. It can handle a total capacity of 6,677,000 TEU annually.

Unlike the old container terminals, the new terminals are modern, capable of accommodating ULCS and are all connected with rail networks. The six operating container terminals have a cumulative capacity of handling 13.7 million TEUs annually. Table 6 presents the capacity of each terminal.

The container throughput of the new port has significantly increased vis-à-vis the old port since 2011. Currently, almost 68% of the total throughput is handled by the new port (see Figure 17 for understanding the trend of the annual throughput for the two ports). In 2019, Busan port catered to almost 75% of the total throughput of the Republic of Korea.

Busan port handles about 95% of the entire transshipment volume of the

Figure 16. Old and new container terminal of Busan port.



Source: AXS Marine (2022).

Table 5. Old Busan container port

	Terminals	Maximum container size
1	U-AM Terminal	Midsized to Panamax
2	Hanjin Gamcheon Terminal	Midsized to Panamax
3	KBCT – Korea Express Busan Container Terminal	VLCS
4	HKT Hutchison Busan Container Terminal	VLCS
5	Busan International Container Terminal	ULCC
6	Hanjin Gamman Terminal	ULCC
7	Global Gamman Terminal	ULCC
8	Dongbu Pusan Container Terminal	ULCC
9	Hutchison Gamman Container Terminal	ULCC

Source: AXS Marine (2022), Alphaliner (2022).

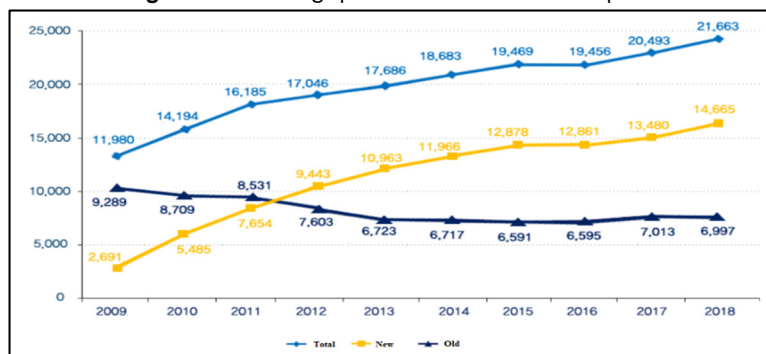
VLCS – Very Large Container Ships; ULCS – Ultra Large Container Ships.

Table 6. New Busan container port

	Terminals	TEU capacity
1	BNP 1-1 (PNIT – Pusan Newport International Terminal)	2,200,000
2	BNP 1-2	2,000,000
3	BNP 2-1b (HJNC – Hanjin New Port Terminal)	2,500,000
4	BNP 2-1a (PNC – Pusan New Port Terminal)	2,000,000
5	BNP 2-3 – BNCT (Busan New Container Terminal)	2,500,000
6	BNP 2-2 (PSA– HPNT)	2,500,000
7	Busan New Port – 2020 expansion A (generic name)	–
8	Busan New Port – 2020 expansion B (generic name)	–
9	Busan New Port – 2020 expansion B (generic name)	–
10	Busan West Container Terminal (3.5 B – Planned)	–
Total		13,700,000

Source: Alphaliner (2022).

Figure 17. Throughput trend: New vs. Old port.



Source: Busan (2022).

Table 7. Busan container throughput statistics

	2,014	2,015	2,016	2,017	2,018	2,019
Import	4,586	4,714	4,801	5,040	5,117	5,280
Export	4,649	4,650	4,819	5,138	5,116	5,074
Transshipment	9,429	10,105	9,836	10,213	11,430	11,636
Coastal	–	–	–	82	–	–
Total	18,683	19,469	19,456	20,473	21,663	21,990
Import percent (%)	24.55	24.21	24.68	24.62	23.62	24.01
Export percent (%)	24.88	23.88	24.77	25.10	23.62	23.07
Transshipment percent (%)	50.47	51.90	50.56	49.89	52.76	52.91
Total throughput growth rate (%)	–	4.21	–0.07	5.23	5.81	1.51

Source: Busan (2022).

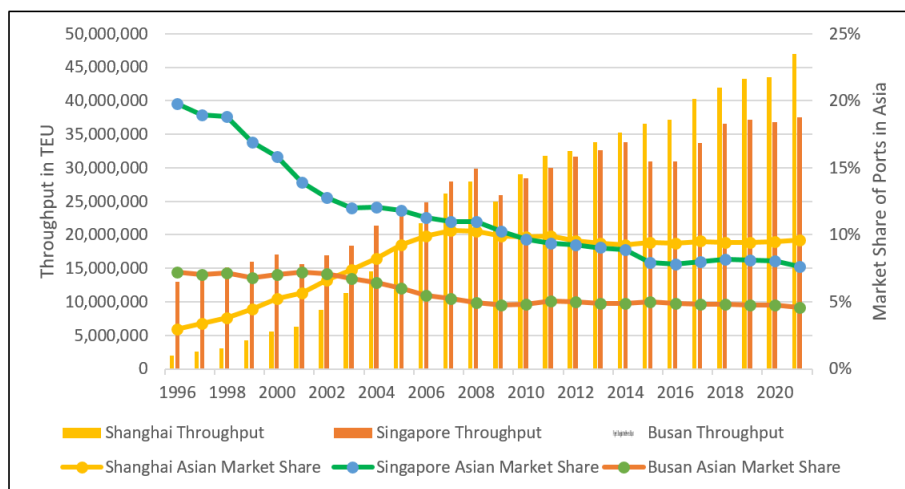
Republic of Korea. The total annual capacity of Busan port is 20.377 million TEUs in 2021. In 2019, 11.636 million TEUs (52.9%) were transshipment volumes, 5.280 million TEUs (24.01%) were import volumes, and 5.074 million TEUs (23.07%) were export volumes. The total export and import volumes have been declining from 55.4% in 2010 to around 47.1% in 2019, and the transshipment volumes have been increasing from 44.3% in 2010 to 52.9% in 2019. This indicates that the Busan port is heading from a traditional export/import port to a transshipment port. The detailed container throughput statistics of Busan are presented in Table 7.

6.2 Challenges and Opportunities

Even though the Asian ports are increasing their throughput volumes, some ports are able to acquire a larger market share, whilst others are looking for their market share. Port of Busan faces fierce competition from the neighbouring Chinese ports. In 2001, Busan was the 3rd largest container port in the world, but it dropped down to the 7th position in 2021. As shown in Figure 18, within the Asian container trade market, the share of Shanghai port has increased from 2.95% in 1996 to 9.60% in 2021, while Busan port has reduced its market share from 7.23% in 1996 to only 4.59% in 2021. Port of Qingdao is marginally lower than Busan in 2019 with a high annual growth rate which surpasses Busan port in 2020. Seven out of the top 10 container ports are located in China which attracts large volumes of cargo and limits the growth of Busan port. Additionally, Busan port has a high dependency ratio on common liner services calling Singapore and Shanghai port (as explained earlier in section 4.8). Since over 50% of the throughputs for Busan are transshipments in nature, this high dependency ratio for Busan on neighbouring ports might be detrimental for the port in both the short and long term.

In the short term, geopolitical tensions such as the US-China trade war, pandemics, or any events and accidents can disrupt the connectivity with the adjacent ports and magnify its impact on Busan port. In the long term, the neighbouring

Figure 18. Throughput and Asian market share for Shanghai, Singapore, and Busan.



Source: Calculated from the Clarksons Research (2022).

Chinese ports can take Busan's transshipment volume with their impressive growth rate. Even though these ports serve the large hinterland of China and are primarily used for exports and imports, their activities cannot be ignored by the neighbouring ports. Furthermore, China is currently the largest manufacturing hub globally, and Busan has strong liner connectivity with Chinese ports. However, as the economy of China is developing and the increasing labour cost can shift the production centres to other Asia countries like Vietnam, Thailand, Indonesia or even Africa. Busan needs to establish strategic partnerships with other countries and diversify its liner network. This will decrease the dependency of Busan port on other regional ports and improve container throughput resiliency for Busan under uncertainties.

Although Busan is the 7th largest port globally, it is still growing continuously with an average rate of about 6.4% over the last ten years. This nevertheless needs expansion to accommodate the growing demand. As there is a plan to establish four new container terminals in the New Busan port, adding about 8–10 million TEU capacity to the port, Busan needs to find additional volumes for this new capacity. As there is a shift in the manufacturing hub adding uncertainties to the global economy, additional volumes can only be achieved by attracting new trading partners/markets.

Despite several challenges for the Port of Busan, there are some interesting in unique opportunities for Busan port. The primary advantage of Busan port is its geographical location; that is, it is located at the junction of Asia (the manufacturing hub of the world because of the low labour cost) and North America (the consuming centre of the world because of the high GDP per capita) which is very similar to the strategic location of Singapore between Asia and Europe. All the liner

services calling Asia / Far East to Europe have a call port to Singapore. Unlike Singapore, there are 30 liner services (out of 159 services) calling between Asia (either Singapore or Shanghai or both) and North America, which do not call Busan port. Busan port should develop strategic trade partners with shipping liners and countries to capture the trade between Asia and North America and increase the port's throughput. These 30 liner services have a cumulative capacity of 160,122 TEUs weekly. Further, as explained in section 5.5, there are no major liner routes which are unique to the Port of Busan. All the major liner services calling Busan port also call Singapore and Shanghai. Busan should also strategically think about developing competitive strategies such as game-theory concepts, network design and port competition by having unique major liner routes (vis-à-vis Singapore and Shanghai) to increase the market share and develop competitive advantages (Anderson et al., 2008; Cullinane et al., 2004; Yap et al., 2006).

Regional and Intra Asia trade is a way forward to improve the transshipment volume for Busan. It could utilise the downgrading (transshipment volumes) trend of the neighbouring ports such as Hong Kong as a case study (Wang and Slack, 2000) to monitor and reform its policies. This could help to understand the needs of several feeder ports and provide an efficient solution to improve the transshipment network for Busan port.

7. Concluding Remarks

Currently, the international trade of commodities is facing turbulence and uncertainties due to the recent pandemic. The impose of port restrictions in China created an opportunity for the Port of Busan to attract more container ships for loading, discharging and transshipment in the region, resulting in an increase in container throughput for a few quarters in 2020. Macroeconomic uncertainties and risks can also increase the port market share for the players who have developed strategies and agility to encash the opportunities. This indicates that just being aware of the possibility is not sufficient; instead, ports should be well prepared for availing these opportunities.

In this respect, this study explores the intra-dependency ratio between Busan, Singapore, and Shanghai ports for containers using common and exclusive liner services from AIS data. It also provides a case study of several challenges and opportunities for the Port of Busan. Even though the maritime industry has been a predominant and well-established industry, there has been limited usage of big data and technological advancement in decision making compared to other industries such as finance, pharmaceutical and even aviation. The data related to the maritime industry, especially for ports, are not readily available. Hence, the decisions related to ports are not always scientific; instead, port managers, policymakers, and others use their experience and qualitative assessments for managerial and operations-

related decisions and develop long-term strategies for ports. Combining management experience and evidence from quantitative data of shipping lines and port connectivity (container lines and trading route related data) can result in robust decision-making.

A major takeaway from this study is that exploring big data in maritime and ports can complement managerial decision making to (i) develop risk management strategies for ports and (ii) retain and increase the port market share. While there was no clear evidence of when and how ports could benefit from the usage of big data in maritime a decade ago, there has been a growing interest and practices to build a decision support system for global supply chain management (Jha et al., 2020) and so as for ports/infrastructure. This emphasises that the usage of big data in maritime is an emerging topic, where ports need to invest more in research to develop competitive advantage vis-à-vis other ports.

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Mega Vessels – Mega Error?

Ulrich Malchow*

ABSTRACT

Does it actually make sense to further increase the size of Ultra Large Container Ships from the shipping line's perspective? Is possibly the opposite of what the growth in size is actually supposed to achieve experienced with the current ship sizes? These questions are followed up on the basis of some fundamental geometric and physical considerations, whereby the focus is on the effects of the longer port stays of the ever larger ships. Based on proportionalities a simple equation for a Fuel/TEU Indicator is introduced to determine the optimum ship size with regard to the fuel quantity and the carbon footprint per TEU for a particular liner service. This is complemented by a Total Cost Indicator for estimating the general optimum ship size. The literature published so far has meanwhile identified doubts on the overall economy of these ships especially when related land based costs are also taken into account but still acknowledge economies of scale effects for the ever growing ships themselves. This paper is intended to scrutinize this thesis.

Key words : ultra large container ship, economies-of-scale, fuel/TEU indicator, container handling factor, carbon footprint

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1. Background

Ultra Large Container Ships (ULCS) with more than 12,000 TEU capacity have become the work-horses of deep sea container shipping. The reason for the growth to currently up to 24,000 TEU, which many industry experts have not believed to be possible some years ago, is the intention to intensify the use of the economies of scale (EoS) in order to further reduce the costs per carried TEU.

Competition in container shipping is mainly by price. Hence container carriers are naturally aiming at being a cost leader. The utilisation of the EoS effects is a powerful tool in this respect as shipbuilding and fuel prices as well as operational cost, i.e., mainly for crewing, are more or less the same for all carriers. It has already been shown that these three types of specific costs per TEU follow asymptotic curves, the course of which becomes flatter with increasing ship sizes (Malchow, 2014; 2015; 2017). The cost advantage per TEU therefore decreases with the size of the ship, while the carriers are facing more operational challenges in terms of nautical restrictions, higher average risks and damages as well as longer port stays which certainly influences the economics as well. However, this is obviously being widely ignored as the increase in ship sizes continues.

Among maritime economists it is meanwhile widely recognised that the ocean carriers are reducing their costs by introducing ever bigger ships on costs of the other players within the intermodal transport chain: if all the public and private investments were taken into account that had to be made in the ports and for hinterland transport in order to cope with the dimensions of the giant ships and the extreme peak loads they are causing, it would have to be concluded that there is no general economic benefit left from the overall perspective (Malchow, 2018; Merk, 2015). In view of the current considerations to go even beyond the current maximum of approx. 24,000 TEU and the fact that the Suez Canal Authority has already decided to further expand the canal, which would allow this jump, it can be taken for granted that even in what has become a very consolidated carrier environment there will be always a shipping line that would blindly follow the path of supposedly limitless growth without deep thinking. Experience has shown that the other market participants would then feel forced to follow in order not to supposedly fall behind in the competition for the lowest slot costs. Hence, another round of the growth spiral would have been started. Such mechanism is still supported by recent studies which claim to have identified EoS effects for the operation of ships of 24,000 TEU and beyond (Alphaliner, 2021; Ge et al., 2019; Rasewsky, 2021). Even hypothetical ship sizes of up to 50,000 TEU are said to provide still economic benefits to their operators (Saase, 2018; Saxon and Stone, 2017).

It is therefore to be examined to what extent the use of these ships still makes sense also from the shipping line's perspective. The focus is on the effects of the inevitably longer port stay of the ULCS, i.e., its dependence from the ship

size and its consequences for ship operation. In order to be able to make generally valid statements, which are independent from the specifics of individual ships and ports, and to avoid highly complex individual calculations, generally valid proportionalities shall mainly be applied.

2. Calculation

Any round voyage is basically consisting of time shares for navigating and port stay, which in turn can be subdivided into the time for coastal navigation (normally connected with speed restrictions) and the time at sea as well as into the time for pure container handling and various waiting times in port:

$$t_{round\ voyage} = t_{navigation} + t_{port} \quad (1)$$

$$= t_{coastal} + t_{sea} + t_{container\ handling} + t_{waiting} \quad (2)$$

Time for coastal navigation (incl. canals) as well as unproductive waiting times in and off the ports (e.g., for shifting of gantry cranes, hoisting/lowering their jib, waiting for tide, pilot or start of shift as well as interruptions of work by labour breaks or weather and of course congestion of ports itself etc.) are considered to be constant in total and independent from ship size and its speed. They are summarised under $t_{coastal+waiting}$. Nowadays a typical round voyage between Northern Europe and the Far East lasts 12 weeks with the following time proportions:¹

$$\begin{aligned} t_{round\ voyage} &= t_{sea} + t_{container\ handling} + t_{coastal\ waiting} \\ &= 59\text{ days} + 19\text{ days} + 6\text{ days} = 84\text{ days} \end{aligned} \quad (3)$$

For the calculation of the required accumulated pure container handling time across all ports, it is assumed that the full (nominal) container capacity of a ship CC [TEU] is being loaded and discharged in each trade direction (wayport cargo and restowage of containers not being considered). With this approach the actual number of ports among the containers are distributed is irrelevant. The respective times in their coastal waters and for waiting within or off the ports are already included in $t_{coastal+waiting}$.

The accumulated pure container handling time across all ports $t_{container\ handling}$ is generally determined by the number of containers to be handled, i.e., the quadruple full container capacity of the ship $4CC$ (2×loading, 2×discharging),

¹ Estimation based on an ocean carrier's liner schedule (Hapag-Lloyd AG, 2021).

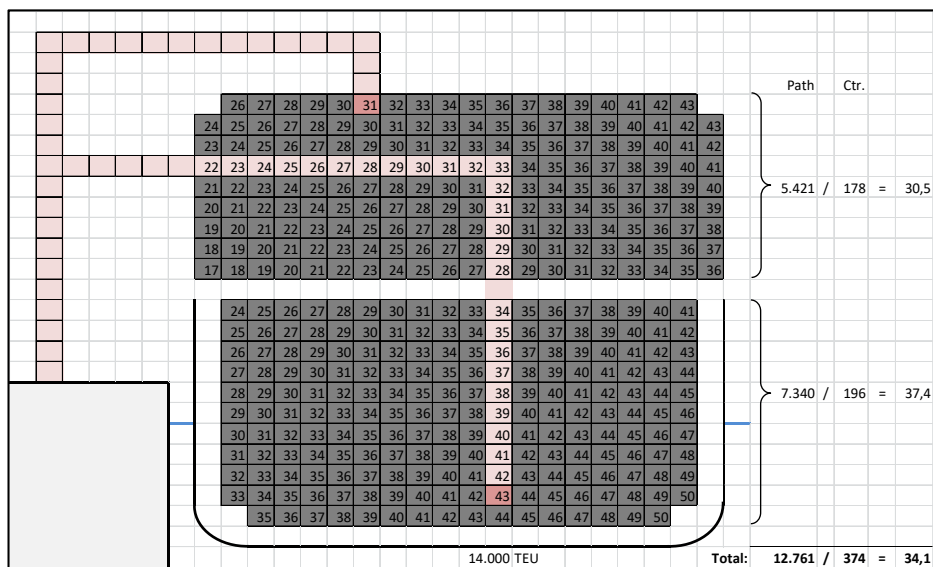
multiplied by the average utilisation rate of the ship $UR [\%]$ which is to be divided by the prevailing TEU factor $TF [TEU/Ctr]$, the average handling rate of the gantry cranes in the particular trade $HR [Ctr/hr]$ and the number of cranes which can be placed alongside the ship n_C :

$$t_{container\ handling} = \frac{4\ CC\ UR}{TF\ HR\ n_C} \quad (4)$$

The handling rate of the gantry cranes depends on their handling speed (trolley and hoisting speed), their standard (e.g., 2-trolley operation, 4-TEU spreader), the skills of the crane driver and the path length of every single container load cycle. The properties of the crane equipment and the resulting speed vary from port to port and do not depend on the ship size (assumption: all ships can be served with the same cranes). Hence they do not need to be further considered as they fall out as a constant factor. Only the path each container has to cover depends very much on the ship size.

In order to determine the average path length the main frame cross-section of several vessels sizes from 1,100 TEU up to 32,000 TEU (projected) are examined with the help of a simple box grid (Figure 1). Sizes above 24,000 TEU are still hypothetical but respective design studies do already exist (Alphaliner, 2021; Rasewsky, 2021). Also geometric design variants within a size class are taken into account (e.g., less beam but instead more layers on the hatch covers or in the hold). The individual path from each stowage position is determined by simply counting the boxes that each container has to cover to a common position

Figure 1. Determination of Trajectory Length.



on the pier that is identical for all containers of all ship sizes. Subsequently for each of the cross-sections the value for the average distance all containers have to cover is determined while the unit of the distance is not relevant. It could be kept as 'boxes' as an equivalent.

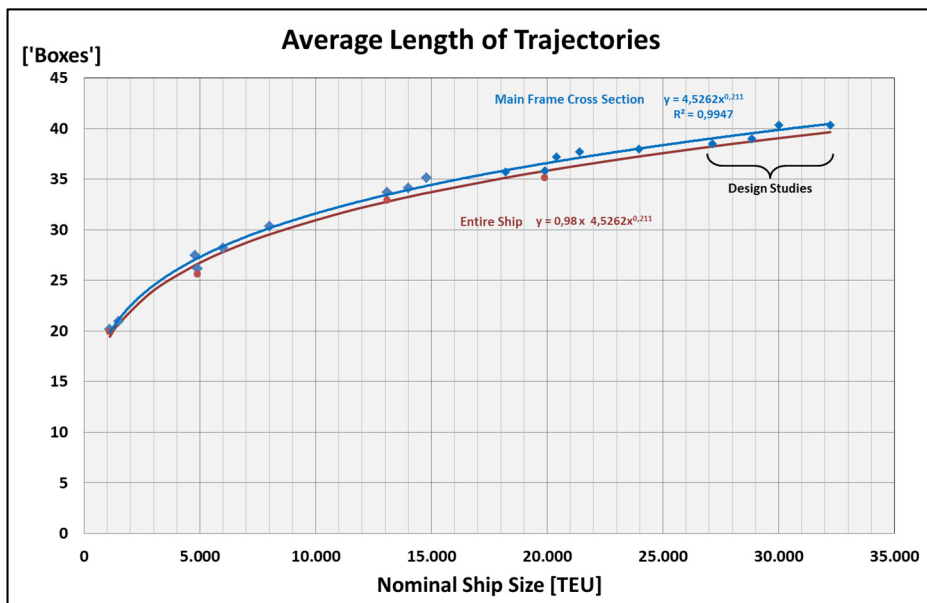
In reality vertical and horizontal motions are combined which reduces the actual length of the path. These shortcuts are assumed to be independent from the ship size. The differences between the individual trajectory curves would remain. Hence, the shortcuts can be neglected and the results from the 'angular' trajectories remain valid. Two common premises which shall be valid for all cross-sections are set in order to compare on the same basis (Figure 1):

1. All containers from/to the cargo hold are crossing the pier at a height of the 6th layer above the main deck.
2. All containers on the hatch covers are lifted by 3 layers before being horizontally moved and v/v.

Even if these premises were not fully in line with the reality their common application would ensure meaningful results. The absolute values of the premises are only of secondary importance as long as they are generally applied.

The examined ship sizes with their various cross-sections result in an exponential function of high regression quality for the average length of the container handling path (number of 'boxes') (Figure 2). The exponent is positive but significantly smaller than '1', i.e., the average path length of the containers grows with the ship size but less than proportionally. Thus, the achievable handling

Figure 2. Length of Trajectories vs. Ship Size.



rate *HR* of the cranes decreases with increasing ship size – also less than proportionally (regardless of the actual performance of the cranes):

$$HR = \frac{\text{crane speed}}{\emptyset \text{path length}} \sim \frac{1}{\emptyset \text{ no.of 'boxes' }} = \frac{1}{f(CC)} = \frac{1}{4.5262 \cdot CC^{0.211}} \sim CC^{-0.211} \quad (5)$$

Equation (5) coincides very well with the statement of Lai (2015) as a practitioner (MD, Modern Terminals Ltd., Hong Kong), who already reported at that time that the average path of the containers during ship-to-shore handling has been extended by approx. 50% when comparing the so-called 'Triple-E' class vessels of Maersk (18,300 TEU) with Panamax vessels of approx. 4,500 TEU.

However, the main frame cross-section is not representative for the entire vessel. Towards the ship's ends the number of containers, in particular within the holds, is getting less. Hence, for 4 exemplary ship sizes (1,100 TEU, 4,900 TEU, 13,100 TEU, 19,900 TEU) the 'path lengths' in terms of crossed 'boxes' are determined for each individual container. Subsequently the average value for the total ship is calculated. Result: for all of the examined ships it turns out that the average value for the entire ship is virtually constantly 98% of the average value for its main frame cross-section. Hence, general validity is assumed. Since this percentage is to be regarded as a constant factor, the general validity of the proportionality according to equation (5) does not suffer.

The number of gantry cranes which can be placed alongside a ship is by nature in proportion to the ship's length even though it is not a continuous relation: the ship's length has to be increased by at least 2×40 ft bays to place one further crane. Furthermore a minimum gap between the cranes has to be kept for safety and operational reasons. In reality ship sizes do not increase continuously either. However, in order to discover a general context all calculations are based on the (unrealistic) assumption of continuous functions.

For the length between perpendiculars *LPP* of container ships Abramowski et al. (2018) have determined following logarithmic regression equation for ships of $CC < 20,000 \text{ TEU}$ ($R^2 = 0.978$) whereas the data supply for ships of $CC > 14,000 \text{ TEU}$ was rather poor with only 7 vessels:

$$LPP[m] = 1.5022 + 0.413355 (\ln CC [\text{TEU}])^3 \quad (6)$$

The length between perpendiculars *LPP* is increased by 5% (average from author's data pool) to get the length over all *LOA* (green line in Figure 3). However, with respect to this particular data pool equation (6) results into too little values for small ships whereas for ULCSs the values are too high.

The cubic law of geometry states that the dimensions of a cuboid grow with the 3rd root of its volume ($L, B, H \sim V^{1/3}$). The high regression quality of a corresponding analysis of a large number of container ships confirms in principle

Figure 3. Length o.a. vs. Ship Size.

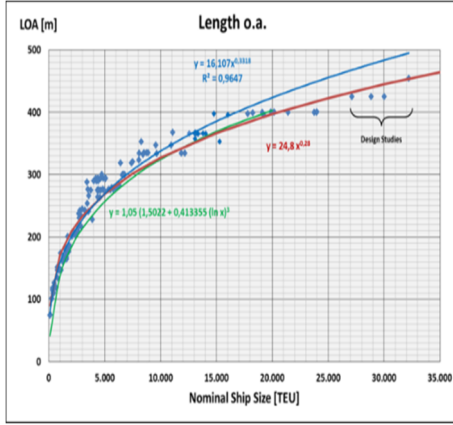
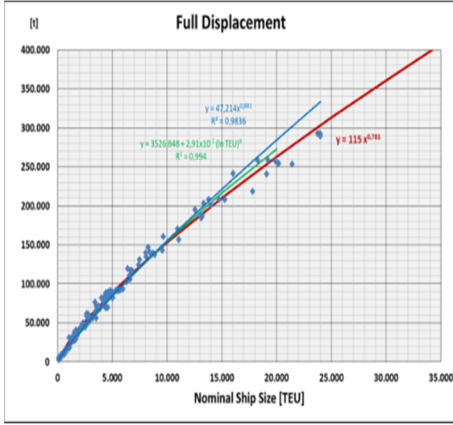


Figure 4. Full Displ. vs. Ship Size.



this law with respect to the ratio of the ship's container capacity CC to its length over all LOA (blue line in Figure 3). However, it can be derived from the diagram that the high regression quality essentially refers to the high number of smaller ships in the author's data pool. For the larger ships of interest, of which significantly less data are available, the regression equation clearly results in ship lengths that are too long. For the actual ULCSs (incl. design studies of up to 32,000 TEU) (Alphaliner, 2021; Rasewsky, 2021) the following exponential equation describes the relation between the length over all LOA and the container capacity CC apparently much better (red line in Figure 3):

$$LOA = 24.8 \ CC^{0.28} \quad (7)$$

Equation (7) is also very much in line with the findings of Park and Suh (2019), who have ascertained for container ships of $CC > 7,000 \ TEU$: $L = 25.08 \ CC^{0.28}$. Accordingly, the number of deployable cranes n_C versus the container capacity CC grows generally even less than according to the cubic law (whereby the actual absolute number of cranes that can be placed is irrelevant in this consideration):

$$n_C \sim LOA = f(CC) = 24.8 \ CC^{0.28} \sim CC^{0.28} \quad (8)$$

When equation (5) and equation (8) are plugged into equation (4) it follows that the accumulated pure container handling time $t_{\text{container handling}}$ basically increases proportionally to the container capacity CC :

$$t_{\text{container handling}} = \frac{4 \text{ } CC \text{ } UR}{TF \text{ } HR \text{ } n_c} \sim \frac{CC}{CC^{-0.211} \text{ } CC^{0.28}} = \frac{CC}{CC^{0.069}} = CC^{0.931} \approx CC \quad (9)$$

$$t_{\text{container handling}} \sim CC \quad (10)$$

The practical proportionality results from the fact that the exponents for determining the handling rate HR (equation (5)) and for the number of deployable cranes n_c (equation (8)) add up to almost zero. I.e., the generally longer container trajectory of bigger ships and the number of gantry cranes which do not increase proportionally to the ship size effect that the accumulated pure handling time of the containers is virtually proportional to the ship's container capacity CC (equation (10)). The average utilization of the ship UR , the speed of the individual crane HR , the number of employed cranes n_c and the actual TEU factor TF can be neglected as they are constant factors when just proportionality is being considered. If the number of cranes cannot actually be increased according to the ship's length (e.g., as not enough are available) $t_{\text{container handling}}$ grows even more than proportionally to CC .

If the duration of a round voyage is to be kept constant while the time for container handling increases, in order to keep the sailing frequency (e.g., for fixed day sailings) and/or not to increase the number of vessels employed, the time at sea must be consequently reduced by a higher ship speed:

$$t_{\text{sea}} = t_{\text{round voyage}} - t_{\text{coastal+waiting}} - t_{\text{container handling}} \quad (11)$$

For the established proportionality between the accumulated pure container handling time $t_{\text{container handling}}$ and the container capacity of the ship CC as per equation (10) the proportionality factor k_i [days/TEU] as so-called 'handling factor' is being introduced (equation (12)). This factor describes the average handling productivity within a particular liner service as the result of the technical performance of the handling equipment and soft factors such as the qualification of staff or the labor shift scheme. k_i is defined to be independent from the ship size but for reference it should be indicated at which size it has been originally measured:²

$$t_{\text{container handling}} = k_i CC \quad (12)$$

² Despite its unit the handling factor k_i [days/TEU] must not be interpreted as the average duration of one move by gantry crane. 'TEU' as denominator refers to the entire nominal container capacity of a ship and not to a single 20ft container. Hence k_i refers to 4 moves of each container ($2 \times \text{loading}, 2 \times \text{discharging}$) of the entire container capacity (taking into account the actual TEU factor which can only vary in its defined bandwidth $TF = 1.0 \dots 2.0 \text{ TEU/Ctr}$). At a given TEU factor k_i describes the average handling standard among all ports within a particular liner service.

The time at sea t_{sea} is given by the fixed distance s_{sea} divided by the average speed of the ship $v_{\emptyset}$. The given duration of the round voyage $t_{round\ voyage}$ and the fixed deductions $t_{coastal+waiting}$ which are independent from the ship size and its speed are summarised under $t_{round\ voyage'}$:

$$\begin{aligned} t_{sea} &= \frac{s_{sea}}{v_{\emptyset}} = t_{round\ voyage} - t_{coastal+waiting} - t_{container\ handling} \\ &= t_{round\ voyage'} - k_i CC \end{aligned} \quad (13)$$

After the formation of the reciprocal following proportionality can be established (as the distance s_{sea} remains constant by nature):

$$v_{\emptyset} \sim \frac{1}{t_{round\ voyage'} - k_i CC} \quad (14)$$

With the help of the so-called 'Admiralty Formula' which is used in preliminary ship design the propulsion power P can be estimated when the displacement Δ [t], the speed $v_{\emptyset}$ [knots] and also the Admiralty Coefficient $C_{Admiral}$ is known. The fuel consumption $\dot{m}_{fuel}$ [tons/day] is directly proportional to the propulsion power (in a certain bandwidth):

$$P = \frac{\Delta^{\frac{2}{3}} v_{\emptyset}^3}{C_{Admiral}} \sim \dot{m}_{fuel} \quad (15)$$

From the available container ship data an almost linear equation of high regression quality for the relation between container capacity and displacement (scantling) can be derived, i.e., the exponent of the exponential equation has a value of almost '1' (Figure 4). The high quality of the almost linear regression equation is again based on numerous smaller ships. For ULCS it provides apparently too high values (for projected ships of $CC > 24,000\ TEU$ no corresponding values for Δ are anyhow available yet). For ships of $CC < 20,000\ TEU$ Abramowski et al. (2018) have found a logarithmic regression equation ($R^2 = 0.994$) whereas with only 7 ships of $CC > 14,000\ TEU$ the related data base was rather poor:

$$\Delta [t] = 3526.844 + 2.91 \times 10^{-3} (\ln CC [TEU])^8 \quad (16)$$

Apparently also this equation results into too high values for big ships (green line in Figure 4). Hence, this equation needs also to be adjusted. Following exponential equation reflects the full range of ship sizes much better (red line in Figure 4):

$$\Delta [t] = 115 CC [TEU]^{0.781} \quad (17)$$

According to equation (15) the fuel consumption $\dot{m}_{fuel}$ [tons/day] for

propulsion is generally proportional to $\Delta^{2/3}$ as well as to v_0^3 (as $C_{Admiral}$ remains practically constant for the category of ULCS it can be disregarded when considering proportionality)³:

$$\dot{m}_{fuel} \sim \Delta^{\frac{2}{3}} v_0^3 \quad (18)$$

Expanding equation (18) with t_{sea} and CC^{-1} results into the proportional dependence of the specific fuel mass per TEU (for propulsion) needed for the entire round voyage (equation (20)):

$$\dot{m}_{fuel} t_{sea} \sim \Delta^{\frac{2}{3}} v_0^3 t_{sea} \quad (19)$$

$$\frac{\dot{m}_{fuel}}{CC} \sim \frac{\Delta^{\frac{2}{3}} v_0^3 t_{sea}}{CC} \quad (20)$$

For Δ , v_0 and t_{sea} the equations (17), (14), and (13) are plugged into equation (20) which is subsequently reshaped:

$$\begin{aligned} \frac{\dot{m}_{fuel}}{CC} &\sim \frac{(115 CC^{0.781})^{\frac{2}{3}} \left(\frac{1}{t_{round\ voyage'} - k_i CC} \right)^3 (t_{round\ voyage'} - k_i CC)}{CC} \\ &\sim \frac{(CC^{0.781})^{\frac{2}{3}} \left(\frac{1}{t_{round\ voyage'} - k_i CC} \right)^2}{CC} = \frac{CC^{-0.479}}{(t_{round\ voyage'} - k_i CC)^2} \end{aligned} \quad (21)$$

$$\frac{\dot{m}_{fuel}}{CC} \sim \frac{1}{CC^{0.479} (t_{round\ voyage'} - k_i CC)^2} \quad (22)$$

Hence, a proportional dependence of the required specific fuel quantity per TEU $\dot{m}_{fuel}/CC$ (over the entire round voyage) from a term just containing the ship size CC , the duration of the round voyage (minus the fixed time shares) $t_{round\ voyage'}$ and the container handling factor k_i is found! The same applies for the specific CO₂ emissions per TEU m_{CO_2}/CC as they are proportional to the respective fuel quantity just by matter of chemistry:

$$\frac{m_{CO_2}}{CC} \sim \frac{\dot{m}_{fuel}}{CC} \quad (23)$$

For $t_{round\ voyage'}$ typical values from real liner services can be inserted, e.g.,

³ According to Schneekluth the same Admiralty Coefficient can be applied for ships of similar design (Schneekluth, 1988) (p. 309). This is actually the case for all ULCS (the only exceptions are the so-called 'Triple-E' class vessels of Maersk (18,300 TEU), which are of twin-screw configuration).

for a typical Northern Europe – Far East round voyage of 12 weeks (equation (3)):

$$\begin{aligned} t_{round\ voyage'} &= t_{round\ voyage} - t_{coastal+waiting} \\ &= 84\ days - 6\ days = 78\ days \end{aligned} \quad (24)$$

The container handling factor k_i can be calibrated for a particular liner service with the help of the actual pure handling time accumulated over the entire round voyage $t_{container\ handling}$ which is to be divided by the nominal container capacity CC of the respective ship (here: 13,000 TEU):¹

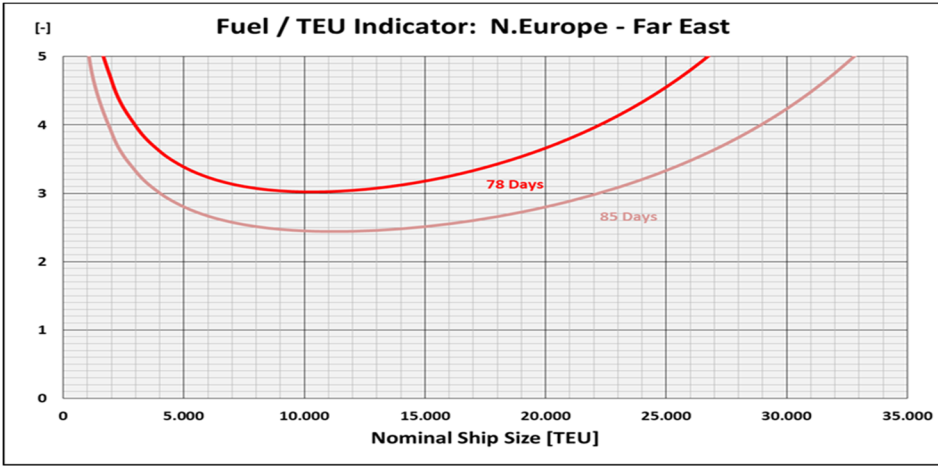
$$k_{13,000} = \frac{t_{container\ handling}}{CC} = \frac{19\ days}{13,000\ TEU} = 1.462 \times 10^{-3} \frac{days}{TEU} \quad (25)$$

The term $(t_{round\ voyage'} - k_i\ CC)^{-2}$ in equation (22) is equivalent to the reciprocal square of the time at sea t_{sea} . The shorter it becomes (to maintain the duration of the round voyage with longer container handling time in port) the more fuel is needed in the course of the round voyage (with quadratic effect). This is counteracted by the EoS effect – but only with the factor $CC^{-0.479}$. This exponential function results into an asymptotical curve, i.e., the EoS effect becomes smaller with increasing ship size. The term $(t_{round\ voyage'} - k_i\ CC)^{-2}$ reflects the basic operational parameters of a particular liner service. Beside CC only $t_{round\ voyage'}$ and k_i are needed as variables to investigate the dependence of the specific fuel demand per TEU from the ship size.

The entire term $CC^{-0.479} (t_{round\ voyage'} - k_i\ CC)^{-2}$ of equation (22) has no meaningful unit but is proportional to the required quantity of fuel per TEU during the round voyage or emitted CO₂ per TEU respectively! It does not state the required fuel quantity itself! The actually needed fuel quantity is just proportional to this newly created '**Fuel/TEU Indicator**'. Hence, it is interesting to see whether the indicator has a minimum and in the affirmative whether it is within the range of already existing or to be expected ship sizes.

It reveals that for a typical Northern Europe – Far East round voyage with $t_{round\ voyage'} = 78\ days$ and $k_{13,000} = 1.462 \times 10^{-3}\ days/TEU$ the *Fuel/TEU Indicator* has indeed a minimum at $CC \approx 10,300\ TEU$ (read from Figure 5)!

Figure 5. Fuel / TEU Indicator vs. Ship Size.



2.1. Derivation

To exactly locate the minimum equation (22) is derived and set to '0':

$$f(CC) = CC^{-0.479} (t_{round\ voyage'} - k_i CC)^{-2} \quad (26)$$

$$f'(CC) = -0.479 CC^{-1.479} (t_{round\ voyage'} - k_i CC)^{-2} + CC^{-0.479} 2 k_i (t_{round\ voyage'} - k_i CC)^{-3} = 0 \quad (27)$$

$$0.479 CC^{-1.479} (t_{round\ voyage'} - k_i CC)^{-2} = CC^{-0.479} 2 k_i (t_{round\ voyage'} - k_i CC)^{-3} \quad (28)$$

$$\frac{0.479 CC^{-1.479}}{CC^{-0.479}} = 2 k_i (t_{round\ voyage'} - k_i CC)^{-1} \quad (29)$$

$$CC^{-1} = \frac{2 k_i}{0.479} (t_{round\ voyage'} - k_i CC)^{-1} \quad (30)$$

$$CC = \frac{0.479}{2 k_i} (t_{round\ voyage'} - k_i CC) \quad (31)$$

$$CC = 0.2395 \frac{t_{round\ voyage'}}{k_i} - 0.2395 CC \quad (32)$$

$$CC = \frac{0.2395}{1.2395} \frac{t_{round\ voyage'}}{k_i} \quad (33)$$

$$CC_{fuel\ min} = 0.1932 \frac{t_{round\ voyage'}}{k_i} \approx 0.2 \frac{t_{round\ voyage'}}{k_i} \quad (34)$$

3. Results

For any liner service the optimal ship size with regard to the minimum quantity of required fuel per TEU and per round voyage which results also into minimum CO₂ emissions per TEU can be easily estimated by applying equation (34). For a typical Northern Europe – Far East round voyage of 12 weeks (see above) the exactly calculated optimal ship size with regard to the lowest *Fuel/TEU Indicator* would be:

$$CC_{fuel\ min} = 10,308\ TEU \quad (35)$$

According to equation (34) the ship size at which the *Fuel/TEU Indicator* reaches its minimum is proportional to $t_{round\ voyage'}$ and inversely proportional to k_i . With other words: the optimum size increases proportionally with the duration of the round voyage (minus the fixed time shares for coastal navigation and waiting times in port) and inversely proportional with the average pure handling time per TEU over the total ship capacity. This in turn means that the longer the variable times of the round voyage (for container handling and sea voyage) and/or the smaller the handling factor the bigger is the ship size where the *Fuel/TEU Indicator* finds its minimum:

$$CC_{fuel\ min} \sim t_{round\ voyage'} \quad (36)$$

$$CC_{fuel\ min} \sim k_i^{-1} \quad (37)$$

E.g., if the duration of the round voyage was extended by slow steaming by 9% to 13 weeks, i.e., $t_{round\ voyage'} = t_{round\ voyage} - t_{coastal+waiting} = 91\ days - 6\ days = 85\ days$ (consequently requiring a 13th ship when the sailing frequency and the transport capacity is to be maintained), the fuel demand per TEU would be naturally significantly less and the calculated minimum of the *Fuel/TEU Indicator* would also increase by 9% to $CC_{fuel\ min} = 11,233\ TEU$ (Figure 5). $CC_{fuel\ min}$ would be correspondingly lower if the duration of the round voyage was shortened.

Beside the handling factor of $k_{13,000} = 1.462 \times 10^{-3}\ days/TEU$ which is determined with a ship size of $CC = 13,000\ TEU$ further curves of the *Fuel/TEU Indicator* for handling factors of $k_{13,000} = 0.75...1.75 \times 10^{-3}\ days/TEU$ are investigated while applying equation (34) (Figure 6): it is quite obvious that increasing the handling efficiency results into a lower curve of the *Fuel/TEU Indicator* as the average speed at sea can be reduced. Furthermore the 'optimum' ship size is moving towards bigger ships and the increase after passing the minimum is the flatter the higher the handling efficiency is. The dashed line in Figure 6 connects the minimum points of each curve. Hence, with regard to the specific fuel quantity and/or the CO₂ emissions per TEU combinations of ship size

and handling factor above that line do obviously not make any sense! For the investigated North Europe – Far East trade Figure 7 illustrates the resulting 'no go area' for combinations of ship size CC and handling factor $k_{13,000}$ above the border line curve where no EoS effect with regard to the fuel quantity and/or the CO₂ emissions per TEU can be expected any more.

Amazing realization out of Figure 6: instead of operating 20,000 TEU ships on a Northern Europe – Far East liner service with a handling factor of $k_{13,000} = 1.462 \times 10^{-3}$ days/TEU twice the number of 10,000 TEU ships navigating at a lower speed were more efficient with regard to the consumed fuel and CO₂ emissions per TEU. Incidentally it should be noted that such configuration would also increase the service quality in terms of a doubled sailing frequency. Obviously only from a handling factor of $k_{13,000} = 0.75 \times 10^{-3}$ days/TEU ≈ 1 min/TEU and less ships of $CC = 20,000$ TEU start to make sense. Provided no tandem or 4-TEU spreaders are used and a TEU factor of $TF = 1.6$ TEU/Ctr applies such value for $k_{13,000}$ would correspond to an average total ship handling rate of:

$$\frac{4 \frac{\text{moves}}{\text{ctr (slot)}} \frac{60 \text{ min}}{\text{hr}}}{1 \frac{\text{min}}{\text{TEU}} \frac{1.6 \text{ TEU}}{\text{ctr}}} = 150 \frac{\text{moves}}{\text{hr}} \quad (38)$$

Figure 6. Fuel / TEU Indicator vs. Ship Size.

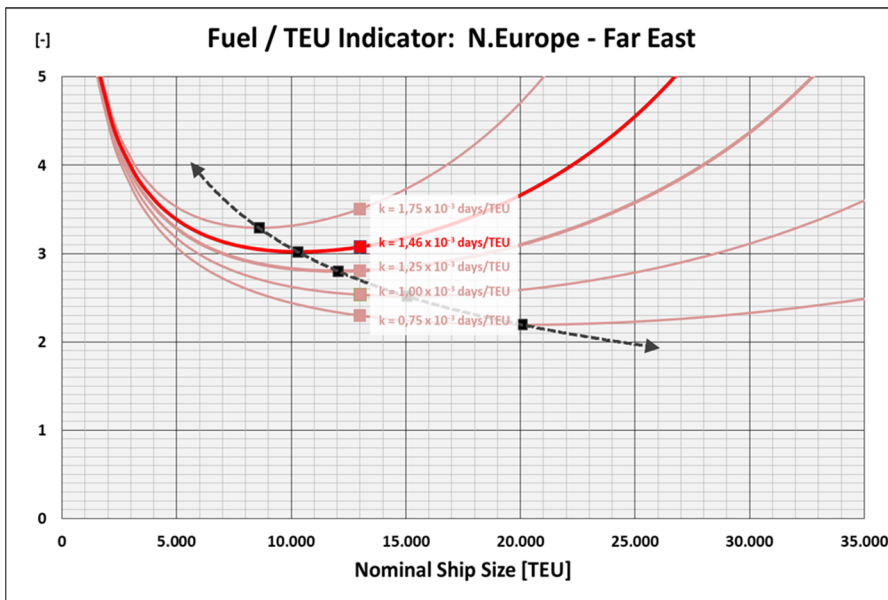
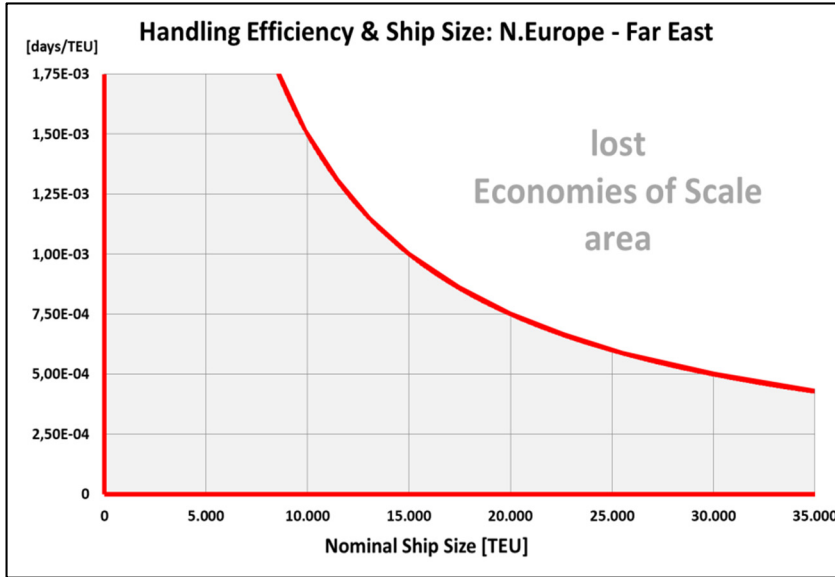


Figure 7. Lost Economies of Scale Area.



If in all ports an average number of e.g., 6 gantry cranes served the ship, it would correspond to an average handling rate of $HR = 25 \text{ moves/hr}$ per crane which is not unrealistic.

A container terminal in Shanghai has recently reported on the biggest ever handled container volume with one ship: within 62 hours 25,775 TEU were handled with a ship of about 23,000 TEU size. Up to 11 gantry cranes were said to be intermittently employed (World Cargo News, 2021). Provided a TEU factor of $TF = 1.6 \text{ TEU/Ctr}$ this corresponds to 260 moves/hr. Assuming that only 8 to 10 cranes were employed in average this corresponds to a handling rate per crane of $HR = 32.5 \dots 26.0 \text{ moves/hr}$.

However, at assumed present average handling efficiencies the common ship sizes in the Northern Europe – Far East trade of today are therefore operating well above the optimal ship size derived from general physical and geometric relations, where the quantity of fuel and thus also the CO_2 emissions per TEU are at a minimum! At an assumed handling factor of $k_{13,000} = 1.462 \times 10^{-3} \text{ days/TEU}$ the *Fuel/TEU Indicator* of the currently largest ships of around 24,000 TEU is in the same range as of ships smaller than 5,000 TEU (when navigating at slower speed)!

4. Overall View

Beside the fuel cost per TEU two further specific cost items are of major importance for the ship operator:

- Capital costs per TEU (based on the ship's construction costs)
- Ship operating costs per TEU (mainly for crewing)

Both types of costs benefit from continuous EoS effects without opposing effects occurring. However, the corresponding curves become flatter in the course of increasing ship sizes. The specific light weight of the ship per TEU (for capital costs) and the manning level per TEU (for operating costs) have been already introduced and derived as suitable and 'neutral' indicators for both types of costs (Malchow, 2015). The advantage of this approach is that these sizes are not influenced and possibly hidden by price, interest level or exchange rate parities resulting from changing market conditions. They are unambiguous values that cannot be falsified, whereby the data on the empty ship weight are unfortunately not easy to obtain. The absolute number of manning is not even required as only the reciprocal relationship is relevant, which means that the relevant costs per TEU are e.g., halved, when the ship size doubles.

All three indicators can be combined to a Total Cost Indicator, whereby it is initially assumed that the three types of costs are each weighted with $\frac{1}{3}$ at a starting point, which appears to be not unrealistic. This point is arbitrarily set at a ship size of 5,000 TEU (slightly larger than the Panamax ships usually operated at earlier days in the Northern Europe – Far East trade) and standardised in such a way that each cost type has a starting value of '1' (without any unit). Then the three curves are added (Figure 8).

For a typical Northern Europe - Far East service, it can be derived from the diagram that under the above mentioned premises for the three types of specific costs, and thus also in the overall view, an initially very strong degression of costs results from the initially dominating EoS effect up to a ship size of about 12,000 TEU. Above approx. 17,500 TEU the influence of the *Fuel/TEU Indicator*, which already rises again from 10,308 TEU onwards (see above), is greater than the ever weaker decrease in capital and ship operating costs. Hence, in the overall view also the Total Cost Indicator rises from there.

Should the fuel costs at the starting point make up actually a larger proportion of the total costs per TEU than the estimated $\frac{1}{3}$, e.g., by a doubled fuel price which consequently would increase the weighting of the fuel costs from $\frac{1}{3}$ to $\frac{1}{2}$ and let the Total Cost Indicator starts at '4', the Total Cost Indicator would already reach its minimum at approx. 15,000 TEU instead of 17,500 TEU (Figure 9). The reverse applies accordingly. In reality the share of fuel costs can be indeed expected at somewhere between $\frac{1}{3}$ and $\frac{1}{2}$ (Garrido et al., 2020).

Figure 8. Total Costs vs. Ship Size.

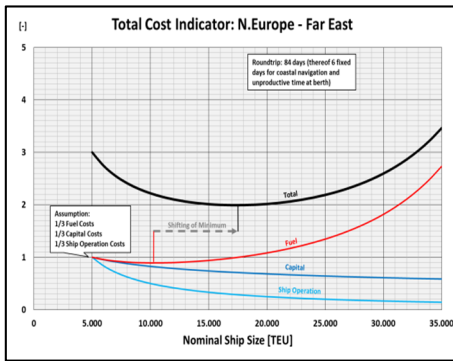
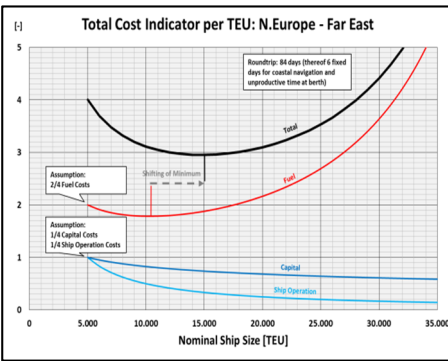


Figure 9. Total Costs vs. Ship Size.
(at doubled fuel costs)



5. Other Trades

Two other important trades in global container shipping have been investigated as well as per Table 1. Across the Pacific smaller ships are employed and the duration of the round voyage is significantly shorter ($t_{\text{round voyage}} = 38 \text{ days}$) while the container handling productivity is higher ($k_{8,500} = 1.2 \text{ min/TEU}$). The course of the curves for the indicators for capital and ship operating costs is by nature independent from the trading area. However, the minimum of the *Fuel/TEU Indicator* is already reached at around 9,000 TEU (Figure 10).

Consequently, also the Total Cost Indicator finds its minimum at a smaller ship size. Due to the shorter duration of the round voyage less time is available to compensate for longer port stays, i.e., the increase in speed and thus the resulting quantity of fuel per TEU has a greater impact (with a quadratic effect).

Table 1. Investigated liner services

	CC [TEU]	$t_{\text{round voyage}}$ [days]	$t_{\text{coastal+waiting}}$ [days]	$t_{\text{round voyage}}'$ [days]	k_i [min/TEU]
Northern Europe – Far East (FE2)	13,000	84	6	78	2.1
Transpacific (PS4)	8,500	42	4	38	1.2
North Atlantic (AL1)	4,500	35	4	31	3.2

Source: Estimate based on an ocean carrier's liner schedule (Hapag-Lloyd, 2021).

Figure 10. Total Costs: Transpacific.

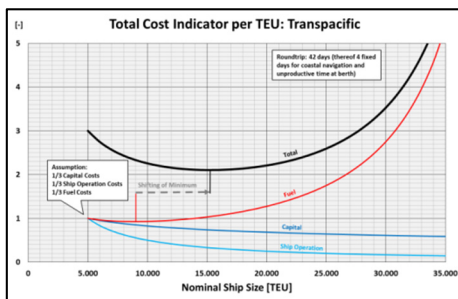
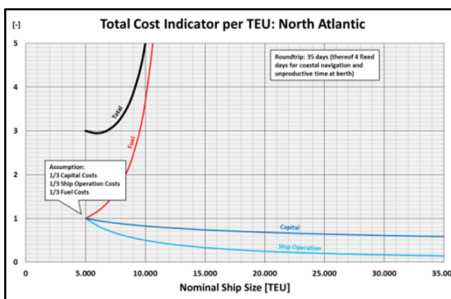


Figure 11. Total Costs: North Atlantic.



On the North Atlantic the ships are even smaller and the duration of the round voyage is even shorter while the overall container handling is significantly less productive ($k_{4,500} = 3.2 \text{ min/TEU}$). Hence, the situation is even more extreme (Figure 11): the minimum of the *Fuel/TEU Indicator* is still below the starting point at 5,000 TEU, which results into the minimum of the Total Cost Indicator being located only slightly above the starting point at about 6,000 TEU. Due to the relatively short time at sea, the required acceleration is extreme to compensate longer handling times. The *Fuel/TEU Indicator* rises so steeply that the technical feasibility at all is in question. The enormous propulsion power which would result from the required speed, would lead to space requirements for the engine plant which would require a completely different ship!

6. Findings

Referring to the initial questioning of the alleged endless EoS effects in container shipping following conclusions can be drawn:

1. The experienced growth in container ship sizes has initially led to significant EoS effects with regard to:
 - Capital costs per TEU
 - Ship operating costs per TEU
 - Fuel costs per TEU
2. The accumulated pure container handling time increases in principle at least proportionally with the ship size (in terms of nominal container capacity). The first reason is that both the accompanying enlargement of the main frame cross-section area (including the deck stowage area) significantly extends the average path lengths of the handled containers between ship and quay.

Secondly the number of placeable gantry cranes can only grow less than proportionally with the container capacity, namely only proportionally with the ship's length. If not enough container cranes were available for the longer ships, the pure handling time would even increase more than proportionately.

3. The longer accumulated pure handling time, which is growing proportionally with the container capacity, means that the speed at sea has to be increased when the duration of the round voyage has to be kept constant. While the EoS effect of rising ship sizes works in principle in favor of the quantity of the required fuel per TEU (at constant speed), the fuel consumption rises with the 3rd power of the speed. At a certain ship size both effects balance out each other. At this point the specific fuel requirement and thus also the carbon footprint per TEU reaches its minimum. For bigger ships, both sizes increase again, i.e., the EoS effect is finite in terms of the specific fuel quantity and the related specific carbon emissions!
4. The optimal ship size with regard to the required quantity of fuel or the carbon emissions per TEU largely depends only on two main parameters of a liner service:
 - Duration of the round voyage minus its fixed time shares for coastal navigation and waiting times in port
 - Average container handling productivity (handling factor)
5. The position of the minimum can be easily estimated with the help of equation (34) by using both parameters.
6. The higher the handling productivity the lower is the Fuel/TEU Indicator, the bigger is the ship size where the Fuel/TEU Indicator reaches its minimum and the flatter is the curve beyond the minimum point. Hence, with an increase in ship size the demand for handling productivity rises sharply. With regard to the specific fuel efficiency and the carbon footprint per TEU the operation of ULCS does not make any sense without a high handling productivity.
7. If also the capital costs and the costs of the ship operation per TEU (mainly crewing costs) are taken into account, which both (in contrast to the required quantity of fuel) benefit from consistent EoS effects, yet another minimum arises in the overall consideration, i.e., the EoS effect is finite also with regard to the total costs!
8. There is an optimal ship size for every liner service, both with regard to the specific fuel requirement (or carbon footprint per TEU) and also with regard to the sum of all essential types of costs per TEU. Both points are not congruent.

The minimum of the required quantity of fuel (or the carbon footprint) is always located at smaller ship sizes than the minimum of the total costs.

9. The location of the minimum of the total costs per TEU is determined by four influences:
 - Curve of the quantity of the required fuel per TEU versus the container capacity
 - Curve of the lightship weight per TEU versus the container capacity (as a synonym for the 'neutralised' capital requirement per TEU)
 - Curve of the crew size per TEU versus the container capacity (as a synonym for the 'neutralised' ship operating costs per TEU)
 - Weighting of the three curves
10. The greater the weighting of the quantity of the required fuel per TEU, the more the minimum of the total costs moves towards smaller ship sizes.
11. The shorter the influenceable times of a round voyage and the slower the average container handling, the steeper are the curves for the required fuel quantity and the more narrow the range of ship sizes that can be reasonably operated in a particular trade.
12. In the investigated trades across the Pacific and the North Atlantic the actually used ship sizes roughly meet the calculated minimum in terms of fuel quantity and are therefore inevitably still below the size where the Total Costs Indicator finds its minimum.
13. With about 24,000 TEU the currently largest ships in the Northern Europe – Far East trade exceed by far the optimal size with regard to the total costs which is even more the case when only the specific fuel amount and thus also the carbon footprint per TEU is being considered!
14. With increasing ship sizes naturally more capacity is provided with the same number of ships, but from a certain point onwards at higher costs and higher emissions per TEU.
15. By increasing the duration of the round voyage (e.g., by slow steaming), the optimal ship size can be shifted towards larger ships. However, more ships would then be required to provide the same transport capacity and sailing frequency, i.e., capital and ship operating costs in relation to the total available transport capacity would increase accordingly.

7. Discussion

The present study is based on the interaction of fundamental geometrical and physical relationships, from which generally valid proportionalities are derived. By using non-monetary values as the basis for a corresponding cost trend, 'neutral' expenses can be derived that are free of 'commercial coincidences' such as market prices, currency parities, volume discounts, negotiating skills or the level of interest rates.

The introduction of the dimensionless *Fuel/TEU Indicator* allows the required conclusions regarding the size-dependence of the fuel requirement per TEU without the need for complex calculations of the absolute consumption of various ships under varying circumstances and various assumptions.

The merger of the *Fuel/TEU Indicator* with the indicators for capital and ship operating costs via normalisation and (arbitrary but realistic) internal weighting to a dimensionless Total Cost Indicator allows for further cognitions of the relationship between ship sizes and overall economics.

The following simplifications have been made and should be assessed:

7.1 Always Full Ships

Although it is currently reality, it cannot be assumed to continue in the long term. However, an assumed degree of utilization would be regarded in any case as a fixed factor and therefore would anyhow fall out of proportionality considerations.

7.2 Wayport Cargo and Restowage of Containers not taken into Account

Related handling processes would further increase the pure container handling time and tend to require even higher speeds at sea to compensate.

7.3 'Angular' Trajectory for Container Handling

In the course of the investigation all containers of all ship sizes are handled 'angular'. Hence, there is no relative error.

7.4 Fixed Container Handling Premises

Even if the premises with regard to the drop-off point and the trajectory corresponded not fully with the actual practice, no relative error would arise if applied consistently.

7.5 Average Handling Path of the Containers for the Entire Ship as a Fixed Ratio (98%) of the Corresponding Value from the Main Frame Cross-Section

The ratio may slightly differ for individual container ships. The error will be minimal.

7.6 Assumption of Continuous Functions

In reality, the number of deployable container cranes versus the length of the ship does not grow steadily, but in stages. The length of the ship itself does not grow steadily with the container capacity either. However, in order to recognize generally valid relationships continuous relationships must be assumed.

7.7 Positioning Times not taken into Account

In reality a part of the pure container handling time relates to the positioning of the container/spreader. The time required is independent from the length of the path covered. Years ago the positioning times were determined to 10 to 25 sec per load cycle. It has been already found out through real time measurements that the positioning times for containers stowed on deck, both during loading and unloading, are longer than for containers stowed in the holds (Kunzmann, 1988). However, the inclusion of the positioning times in $t_{\text{container handling}}$ would not have resulted in any additional insight and therefore equation (34) is not questioned.

7.8 Hatch Cover Handlings not taken into Account

As a first approximation, it is assumed that the number of hatch covers is proportional to the container capacity of a ship. In this respect, they cannot be subsumed in the waiting times t_{waiting} , which is by definition size-independent, but should be rather included in $t_{\text{container handling}}$. Equation (9) should actually be extended by a corresponding factor. However, this would not question the validity of equation (10) in general.

7.9 Use of Regression Equations

The application of the four regression equations for ...

- Length of the container path during handling
- Ship length
- Full displacement
- Lightship weight

... as a function of the container capacity $f(CC)$ of a ship is the basis of the investigation. They were determined from a data pool of numerous ships and either have a high regression quality (and thus represent the geometric and physical relationships very well) or had to be (permissibly) adapted for apparent reasons.

7.10 Application of the Admiralty Formula and the Admiralty Coefficient

In shipbuilding the Admiralty Formula (equation (15)) is used in the preliminary design phase for approximate calculations. It is not used to precisely calculate the required propulsion power.³ However, the formula contains the dependence of the propulsion power from the 3rd power of the speed as well as from less than the proportionality from the displacement. The 3rd power of the speed derives from the physical theory. However, in reality the exponent is often even bigger than '3'. That is why already years ago Völker formulated a 'New Admiralty Formula', which better represents the reality compared to the traditional formula (Schneekluth, 1988):

$$P = \frac{\Delta^{0.567} v_0^{3.6}}{C_{Admiral}} \quad (39)$$

With these modified exponents according to Völker's formula, both the influence of the speed and the EoS effect are stronger. Hence, the curve of the *Fuel/TEU Indicator* was more 'tube-shaped'. However, the basic shape of the curves and in particular their minimum were retained.

7.11 Proportionality between Fuel Consumption and Propulsion Power

Within the range of 70% ... 85% MCR the specific fuel consumption (in terms of g/kWh) of slow speed two-stroke main engines can be assumed as a constant factor ($\pm 1.5\%$). The main engines of container ships are usually operated approx. 75% of their running hours in this range (MAN Energy Solutions, 2018).

7.12 Quantity of Fuel during Coastal Navigation and for Auxiliary Power

Strictly speaking, the quantity of fuel that is burned during the fixed time of coastal navigation (mostly at limited speed) fully benefits from the (albeit flattening) EoS effect and should also be taken into account. The entire curves in Figure 5 would therefore be overall a little higher and the minimum would be shifted a little towards bigger ships. However, for a typical Northern Europe – Far East round voyage with 4-5 days of coastal navigation (at usually reduced engine output) compared to 59 days at sea, the relative error in the location of the

minimum would be marginal.

The considerable quantity of fuel that the auxiliary engines require for each refrigerated container is not of interest for the calculation of the minimum, as this quantity does not depend on the size of the ship but can be viewed as a constant per refrigerated TEU. This also applies when the time at sea is reduced. As long as the duration of the round voyage is kept constant it does not matter whether the ship is at sea or in port where the containers have to be refrigerated as well (as long as no shore power is used).

7.13 Growing Engine Plant

It is part of the EoS effect that the relative share of weight and volume of the propulsion plant decreases with increasing ship size (at constant speed). However this effect is more than compensated when the speed increases significantly. The respective propulsion power would require an increasing share of ship space and light weight (leaving less deadweight). That would generally shift the minima further towards smaller ship sizes and would also increase the capital cost per TEU in twofold: the ship as a whole would become more expensive while at the same time less container capacity would be provided (which also would increase the fuel quantity per TEU). Accordingly, the capital cost per TEU would no longer be an asymptote and the rise of the *Fuel/TEU Indicator* would be much steeper. Hence, the EoS effect would stop much earlier. However, these aspects have not been taken into account in the instant considerations. Actually it must be concluded that the curves in Figure 6 are presumably still too positive!

7.14 Port Costs not taken into Account

A large part of the port costs relates to the handling of the containers and is therefore independent from the ship size. Hence, they can be neglected without any loss of accuracy. All ship-related port charges are mostly based on the gross tonnage which is subject to a proportional relationship with the container capacity, i.e., there are no EoS effects existing in this regard. EoS effects would only come into play if e.g., berth charges are based on the ship's length or even if discounts were granted for ULCS (which is actually the case in some ports).

7.15 Arbitrary Weighting and Standardization

In fact, the weighting of the three cost variables each with a contribution of $\frac{1}{3}$ to the total costs is arbitrary (but not unrealistic) as is the standardised starting point at 5,000 TEU. However, the starting point is irrelevant for the position of the minima. With a weighting of $\frac{1}{2}$ for the fuel quantity per TEU, which was also carried out, the range of the possible locations of the total cost minima can be well

estimated. With the determined relationships, each individual weighting can be carried out at any selected starting point for any specific liner service – with corresponding individual conclusions.

The gained findings are based on the analysis and combination of geometric and physical effects and, even when taking the above simplifications into account, allow general conclusion to be made. A surprising finding is e.g., that ship sizes of 24,000 TEU are much too large in terms of their 'carbon footprint' per TEU. Two 12,000 TEU ships, which would navigate more slowly while the round voyage duration remains unchanged, would be significantly more efficient in this respect. Additional logistical advantages would be apparent anyhow: twice the sailing frequency could be provided and the terminals would be relieved from heavy peak loads. But also with regard to the total costs, 24,000 TEU seems to be already significantly too large.

All the above findings are of course subject to an exact calculation for each individual case, taking into account the actual steps in ship size growth, costs levels and their weighting. The gained insight of existing minima even with regard to the total costs per TEU over the ship size makes the exact recalculation with absolute values extremely necessary. At present times of high awareness regarding climate change this is even more the case when it comes to the determination of the ship size with the lowest possible carbon footprint per TEU.

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Influence of Structural Variation of Container Shipping Industry towards Ocean Freight Forwarders

Hua-An Lu * · Li Xuan Wu **

ABSTRACT

The industry of container shipping lines (CSLs) has undergone a substantial structural change recently, including the withdrawal of CSLs and reshuffling for strategic alliances. Previous research was limited on the influence of an industrial restructure of CSLs towards the operations of ocean freight forwarder (OFF) companies. This study used the similarity aggregation method (SAM) to complement this gap from a survey of 50 OFFs with varied experiences in Taiwan. The results revealed that OFFs paid more attention to the rights and obligations for cargo claims and observed details for operational dynamics of CSLs. They also had a greater focus on risk management. OFFs perceived the competitive pressure to generate more business that could be found from their rapid responses to the changes of shipper logistical decision-making and requirements. Interestingly, brand reliability and service quality for existing CSLs had no apparent variations.

Key words : container shipping lines (CSLs), strategic alliances, ocean freight forwarder (OFF), similarity aggregation method (SAM)

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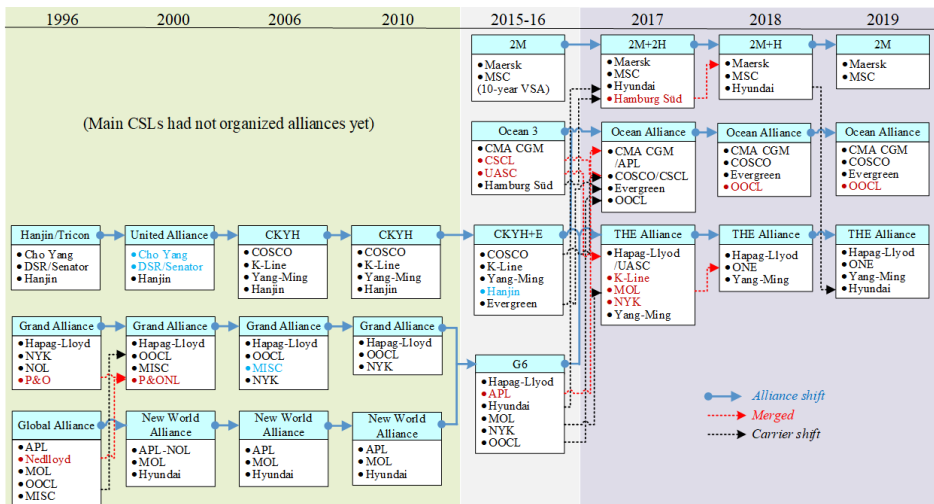
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1. Introduction

The industry of global container shipping lines (CSLs) has undergone dramatic changes as to the structure of companies since 2015. Some famous and large carriers have been merged, such as Neptune Orient Lines Limited, China Shipping Container Lines (CSCL), and United Arab Shipping Company; or some even withdrew from this industry, such as Hanjin Lines. Three Japan-based primary shipping lines, NYK, K-Line, and MOL, divided their container operation systems into a merged new brand called Ocean Network Express (ONE) in 2018. Although the Orient Overseas Container Line (OOCL) still existed, most equity shares were acquired by COSCO Shipping. These CSLs were ranked top 20 in the supply of ship fleet capacities and joined strategic alliances (SAs) for many years. Since the end of 1995, the first generation of SAs started an operational model of both competition and cooperation. SAs of CSLs must confront members' shifts for every contracted term because of the variation of freight rate levels and the operation status of individual carriers. Durations of 2006 to 2010 and after 2018, the constitution of SAs revealed relatively stable (Figure 1). The reshuffling of SAs coped with the above events has formed entirely new industrial operating systems for shipping carriers. Simply put, industrial concentration levels for CSLs are growing; and co-operation and competition among the larger companies are tighter than before (Varbanova, 2017).

The main fuse hidden in these events is competition regarding the continuous upsizing of containerships among CSLs. The larger the ship sizes, the greater

Figure 1. Historical development for strategic alliances of CSLs.



CSL, container shipping lines; UASC, United Arab Shipping Company; NOL, Neptune Orient Lines Limited.

the benefits of economies of scales. Larger containerships increase investment and operation costs and establish a higher barrier for carriers considering entering the market. Short-sea services were reasonably affected by a cascading effect of deployed ship sizes (OECD, 2015).

Shipping lines are at the top of the ocean transportation chain, which consists of many other downstream stakeholders, such as port operators, ocean freight forwarders (OFFs), and logistics integrators, among others. This study focuses on any possible influence from the new operating environment for global CSLs towards the operations of OFFs because freight forwarding businesses are most directly concerned with shipping lines. In particular, the sudden closure of Hanjin Lines in 2017 had caused an unprecedented influence on global OFFs to protect the rights of shippers and claim benefits.

This study explores how OFFs have managed their operations during this period of dramatic change that flowed upstream and what this influence was on their operations. This study proposed 18 factors after the preview of industrial and academic experts to design a questionnaire to investigate 50 practitioners of OFFs in Taiwan. This questionnaire asked respondents to express agreement levels for all factors. For exploring the recognition of all expert opinions, this study used a fuzzy similarity aggregation method (SAM) to rank all aspects and made an insightful and sensitivity analysis based on the differences of respondent positions, experiences, and business classifications. These results can clarify the real concerns for OFFs facing a new operating environment driven by larger players' withdrawal in the upstream industry. CSLs can understand their operational partners' anxious issues when they appear enormous internal alternation from this study, and then take appropriate countermeasures not to disturb the whole market.

The following section reviews previous studies by examining the service of OFFs and evaluating the factors involved in selection carriers. Section 3 introduces the methodology of the proposed fuzzy SAM and the operation steps. Section 4 describes the research design and investigation results. Section 5 reports and discusses results obtained from the SAM analysis. The final section concludes with the findings of this research and possible future areas of study.

2. Literature Review

Freight forwarding services depend on the supply conditions provided by CSLs. A large-scale variation of the industrial environment of CSLs will affect the operation resources of OFFs. This section reviews the services offered by OFFs and then examines the evaluated criteria of OFFs and shippers in selecting CSLs. The third part of the literature review focuses on the influence of the CSLs industry environment on freight forwarders.

2.1 Services of Freight Forwarders

Freight forwarders are agents who provide related services for consignment deliveries on their own or in a client's name. They always organize the transportation of shipments with various characteristics and assumes responsibility for their delivery. Freight forwarders play the role of carriers when dealing directly with shippers; in contrast, they change their position while consigning shipments to actual carriers. Many larger OFFs have expanded their services with integrated logistics management for cross-country operations (Burkovskis, 2008).

Service qualities or attributes of OFFs have attracted various studies seeking to clarify the factors that affect shipper selection for consigned shipments. Reliability, service, and price are primary dimensions that shippers consider (Kilibarda et al., 2016; Perlman et al., 2009). Reliability presents the gaps between the perceived and expected values of shippers. Aggregated and integrated services reveal the requirement of globalization businesses for contemporary producers. The excellent transit handlings with a rationalization of freight rates are the noticeable conditions to present the competitive advantages of forwarders (Lin and Liang, 2011). Service qualities through information tracing, availability of cargo space, the competency of emergency handling, the ability of claims, and freight rates might show a higher priority for improvement (Yang, 2012). Notably, customer response, information technology, and knowledge management affected organizational performance for OFFs (Shang and Lu, 2012). Innovation capability and firm performance of OFFs have been examined to have a positive and significant relationship (Yang, 2012).

The service conditions of OFFs are pretty crucial for their customers; however, most parts of these conditions depend on the provision of CSLs. A considerable variation of the industrial dynamics of CSLs affects the arrangement of forwarding arrangement inevitable and right.

2.2 Shipping Line Selection of Shippers and Ocean Freight Forwarder (OFFs)

Shipping line selection is crucial because the cooperating relationship might need to be maintained for a long time between the shipper/forwarder and any carrier. In the early operation environment, carriers' door-to-door elapsed time and timing-related services were the unique deterministic criterion of carrier selection decision (Brooks, 1990; Lu, 2003). As the complexity of global logistics operations increased, more criteria, such as freight rates, scheduling, carrier reputation, slot availability, and on-time arrival/departure, became the additional conditions in carrier selection (Kannan, 2010; Lu, 2013). To play an intermediary role, OFFs still take shipper needs into account in carrier selection. Customs clearance efficiency and transport security are two critical factors correlated with integrated logistics (Ho et al., 2017).

The competitiveness of CSLs usually affects OFFs and shippers in selection. Schedule reliability, document accuracy, service quality, freight rate, and door-to-door service and environment significantly reflect the competitive performance among CSLs (Fanam et al., 2018). For specific markets, such as between Taiwan and southern China, different operation scales of OFFs reveal various consideration focuses. Large companies focused on the following dimensions: freight charges and information technology; whereas smaller companies preferred to focus on service performance and the reputation of the CSLs (Wen and Lin, 2016).

Although previous research (Ergin et al., 2022) indicated that the changes in world trade and maritime transport made the customers' expectations vary, including shippers, consignees, and OFFs, the factors in selecting CSLs, reviewed from the studies mentioned above, mainly focus on freight rates, service conditions and qualities, and schedule reliabilities. Customer relations-related criteria have become more critical than the freight criterion. This study supports the phenomenon that the whole chain of maritime transport for container deliveries is changing, which is also proposed by this study.

2.3 Industry Environment Influence on Freight Forwarders

The enormous variation from the industry of CSLs did not occur frequently. The Ocean Shipping Reform Act of 1999 in the United States induced a dramatic change to the industry of CSLs. This act almost reformed the maritime operation practice at that time. The challenges and opportunities of the intermediaries of non-vessel operating common carriers (NVOCCs) made a greater investment in information technology and other advanced tools and processes for supply chain management (Clott, 2000). Greater service values then were achieved than the traditional selling approach.

CSLs used cost-oriented competition strategies to benefit from economies of scale by ship enlargement, i.e., the more quantities of transported goods with the lower unit transport costs (Lu and Yeh, 2019; Tran and Haasis, 2015; Valentine et al., 2013). Only higher slot utilization can bring additional profits to the shipping lines. However, if deep ocean loops visit too many ports, there is a decrease in the benefits of the high load factor because extra port time and berthing cost further decrease.

Most of the critical perspectives of top managers in CSLs to operate mega-ships are concerned about the ship lines themselves (Lu and Yeh, 2019), like increases in investments in building or leasing containers, changes of service networks of shipping lines, and management of empty container repositioning. Still, some factors will directly alter the logistics system operations, such as seaborne feeder services and inland transportation. The relationships between CSLs and OFFs are also affected by a significant burden to fill up a ship to capacity.

The changing features because of such chain effects affect the operation and service of OFFs. Most other partners in the transportation chain are not necessarily favorable for mega-ships (OECD, 2015). Some possible misgivings are the

upsizing ships, such as service frequency reduction, risks concentrating in a single vessel, delivery disruptions or delays, port hinterland infrastructure and connectivity, peak congestion, and delay for truck companies, among others that may affect all stakeholders.

OFFs play the interface role between CSLs and shippers, but most previous studies discussed the service and selection relationships in the normal operating environment of container shipping. The CSL industry is currently situating a significant alternation on a higher concentration of service conditions because of the reduction of larger players. The influence of this phenomenon might gradually leaven to alter the service resources and even the priorities of company management of OFFs. This study attempts to dig out some valuable findings for the perceived influence of OFFs.

3. Research Design

The upstream changes of industrial structure caused different perceptions to different operation levels in OFF companies. The employees confronted such critical moments and might perceive undetermined or fuzzy recognition for the related topics. This study attempts to combine subjective opinion with fuzzy techniques for a group consensus result. This study exploited the SAM to consider the possible difference in recognitions because of the difference of backgrounds and experiences of respondents. This treatment can demonstrate more reliable results to ensure the market judgment for our topic. The following sub-sections firstly introduce the concept of SAM and then the investigation results.

3.1 Method

This study infers the similarity calculation equation for triangular fuzzy numbers to develop the operation procedure of SAM. This approach is more accessible than using trapezoid fuzzy numbers proposed by Hsu and Chen (1996). The calculation of exact similarity with triangular fuzzy numbers in the Section 3.1.1 is also the contribution of this study. Based on this calculation, the following two sections provide the operation steps of SAM and the defuzzification processes.

3.1.1 Similarity measure concept

Fuzzy techniques can aggregate opinions from multiple experts evaluating an uncertain decision environment. The fuzzy concept comes from a judgment that might be expressed in a numerical range with a different membership strength to represent the possible decision determination. Let X be a universal set. A fuzzy set A in X is characterized by a membership function $u_A(x)$ associated as a real number

in the interval between 0 and 1 with each point in X . The value of $u_A(x)$ at x represents the membership grade of x in A .

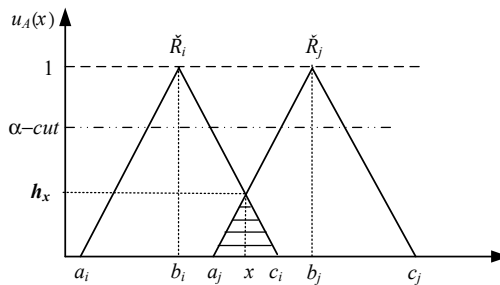
A triangular fuzzy number is a popular method of defining the membership function to express a decision maker's fuzziness. Equation (1) expresses the membership grades for a triangular fuzzy number A in real line $\Re$ referring to $u_A: \Re \rightarrow (0, 1)$, where $-\infty < a \leq b \leq c < \infty$ (Dubois and Prade, 1978). The grade of b represents a maximal grade or the most probable value of membership in A , i.e., $u_A(b) = 1$. The interval (a, c) is the range of this set's lower and upper bounds, for which length also represents A 's fuzziness. Thus, a triangular fuzzy number A can be represented by 3-tuples $A = (a, b, c)$.

$$u_A(x) = \begin{cases} (x - a) / (b - a), & a \leq x \leq b \\ (c - x) / (c - b), & b \leq x \leq c \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

Suppose two experts have their estimates $\tilde{R}_i$ and $\tilde{R}_j$ represented by triangular fuzzy numbers, but assumed they have a common intersection at some α -level cut, $\alpha \in (0, 1]$. Figure 2 and equation (2) express that the agreement degree $S(\tilde{R}_i, \tilde{R}_j)$ is defined by the proportion of the consistent area to the total area, also known as a similarity measure function (Zwick et al., 1987).

$S(\tilde{R}_i, \tilde{R}_j)$ can be further inferred as the flowing with the elements of two triangular fuzzy numbers $R_i = (a_i, b_i, c_i)$ and $R_j = (a_j, b_j, c_j)$ and expressed as Equation (3). If two estimates are the same, i.e., $\tilde{R}_i = \tilde{R}_j$, $S(\tilde{R}_i, \tilde{R}_j) = 1$. In contrast, if

Figure 2. Concept of similarity measures for two triangular fuzzy numbers.



$$S(\tilde{R}_i, \tilde{R}_j) = \frac{\int_x (\min \{\mu_{\tilde{R}_i}(x), \mu_{\tilde{R}_j}(x)\}) dx}{\int_x (\max \{\mu_{\tilde{R}_i}(x), \mu_{\tilde{R}_j}(x)\}) dx} \quad (2)$$

two estimates are entirely different, $S(\tilde{R}_i, \tilde{R}_j) = 0$. Higher a $S(\tilde{R}_i, \tilde{R}_j)$, the higher the consistency or similarity.

$$\frac{x - a_j}{b_j - a_j} = \frac{c_i - x}{c_i - b_i} \rightarrow x = \frac{c_i b_j - b_i a_j}{c_i - b_i + b_j - a_j} \text{ and } h_x = \frac{c_i - a_j}{c_i - b_i + b_j - a_j}$$

$$S(\tilde{R}_i, \tilde{R}_j) = \frac{\frac{1}{2}(c_i - a_j) \times \frac{c_i - a_j}{c_i - b_i + b_j - a_j}}{\frac{1}{2}(c_i - a_i) + \frac{1}{2}(c_j - a_j) - \frac{1}{2}(c_i - a_j) \times \frac{c_i - a_j}{c_i - b_i + b_j - a_j}}$$

$$S(\tilde{R}_i, \tilde{R}_j) = \frac{(c_i - a_j)^2}{(c_i - a_i + c_j - a_j) \times (c_i - b_i + b_j - a_j) - (c_i - a_j)^2} \quad (3)$$

3.1.2 Similarity aggregation method (SAM) operation steps

Suppose the fuzzy numbers of n respondents for a question in an item. Let $S_{ij} = S(\tilde{R}_i, \tilde{R}_j)$ to represent the measured similarity of respondents i and j . Applying the operation proposed by Hsu and Chen (1996) to the triangular fuzzy numbers. The operational steps are described as follows:

Step 1: Calculate agreement degrees for every two respondents and construct the agreement matrix (AM). This matrix is defined as $AM = [S_{ij}]_{n \times n}$, $i, j = 1, 2, \dots, n$. Each element S_{ij} can be calculated with equation (3).

Step 2: Calculate the average agreement degree (AAD) for respondent i by Equation (4).

$$A(E_i) = \frac{1}{n-1} \sum_{\substack{j=1 \\ j \neq i}}^n S_{ij}, i = 1, 2, \dots, n \quad (4)$$

Step 3: Calculate the relative agreement degree (RAD) for respondent i by Equation (5).

$$RAD_i = \frac{A(E_i)}{\sum_{i=1}^n A(E_i)}, i = 1, 2, \dots, n \quad (5)$$

Step 4: Set the relative weights of the importance levels for all respondents, i.e., r_i , $i = 1, 2, \dots, n$. Then, calculate the important degree w_i for all respondents by Equation (6).

$$w_i = \frac{r_i}{\sum_{i=1}^n r_i}, i = 1, 2, \dots, n \quad (6)$$

Step 5: Calculate the consensus degree coefficients (CDC) for all respondents by Equation (7) with a given β value, where $0 \leq \beta \leq 1$.

$$CDC_i = \beta \times w_i + (1 - \beta) \times RAD_i, i = 1, 2, \dots, n \quad (7)$$

Step 6: Calculate the aggregation result $\tilde{R}$ with fuzzy multiplication and addition by Equation (8). $\tilde{R}$ represents an overall fuzzy number of combining every fuzzy opinion of each respondent.

$$\tilde{R} = \sum_{i=1}^n CDC_i \otimes \tilde{R}_i \quad (8)$$

The final results of SAM present triangular fuzzy numbers for every question proposed by this study. They can be ranked by their priorities using a certain defuzzification method.

3.1.3 Defuzzification for ranking

The defuzzification process transforms a fuzzy number into a proper and crisp value compared to other fuzzy numbers. Some defuzzification methods for triangular numbers have been proposed. This study used the method proposed by Chen and Hsieh (2000) and equation (9) to defuzzy the final results of SAM. This method is similar to the center of gravity (COG) method and easy to operate. Further, the fuzzy ranking principles are followed as Equation (10) to compare two fuzzy numbers A_i and A_j .

$$D(A_i) = \frac{a_i + 4b_i + c_i}{6} \quad (9)$$

$$\begin{aligned}
A_i > A_j &\Leftrightarrow D(A_i) > D(A_j) \\
A_i &\approx A_j \Leftrightarrow D(A_i) = D(A_j) \\
A_i < A_j &\Leftrightarrow D(A_i) < D(A_j)
\end{aligned} \tag{10}$$

3.2 Investigation

For exploring the influence of the industrial environment change of CSLs, this study collected possible alternations from the literature to invite nine experts to preview the appropriateness of the proposed question items. The panel of this focus group consisted of five senior managers from freight forwarder companies and four professors who continuously devoted themselves to marine shipping research. Then, this study distributed the revised questionnaire to 50 industrial experts to investigate their agreement levels for all question items. Primary processes in the whole research design are described as follows.

3.2.1 Questionnaire contents

The designed questionnaire at the first phase consisted of 16 influential factors extracted from the support references. Most experts deleted the factor of “OFFs perceive the sales representatives of CSLs lacking sufficient advanced knowledge and capability.” They provided suggestions to modify the other six factors by precisely describing the situation of changes, such as revising “Choice for available cooperated carriers changes” as “Choice for available cooperated carriers decreases.” Furthermore, three factors stemmed from their observation and were implemented to be appended. These question items included “OFFs should quickly respond to the changes of logistical decision making from shippers,” “OFFs care more about risk management than before,” “OFFs track CLSs’ operation dynamics more in detail.” Table 1 shows the contents of the ready questionnaire to distribute to the next round of experts.

Table 1. Contents of the distributed questionnaire and support references of factors

No.	Factors	Support references
1	Freight rates offered by carriers are obviously changed.	Lin and Liang (2011); Lu (2013); Wen and Lin (2016); Ho et al. (2017)
2	The route mixes to provide shippers decrease.	OECD (2015); Lu and Yeh (2019); Ho et al. (2017)
3	The provisioning capability of empty containers to shippers gets better.	Ho et al. (2017); Lu and Yeh (2019)

4	Truck fees increase because of ship call changes.	OECD (2015)
5	The choice for available cooperated carriers decreases.	Lu et al. (2006)
6	Control ability of forwarders for ship slots decreases.	Lu (2013); Wen and Lin (2016); Lu and Yeh (2019)
7	Handling and additional charges increase.	Lin and Liang (2011); Ho et al. (2017)
8	Transport reliability of CSLs decreases.	Lu (2013); Wen and Lin (2016); Lu and Yeh (2019)
9	Service quality of CSLs decreases.	Lin and Liang (2011); OECD (2015); Lu and Yeh (2019)
10	Brand reliability of CSLs decreases.	Lu et al. (2006); Lu (2013); Wen and Lin (2016); Ho et al. (2017)
11	OFFs should quickly respond to the changes in logistical decision making from shippers.	<i>Proposed by the focus group</i>
12	OFFs change the perception to an e-commerce application.	Lin and Liang (2011)
13	The pressure of getting more freight businesses increases.	Grimstad and Neumann-Larsen (2013); Lu and Yeh (2019)
14	OFFs care more about risk management than before.	<i>Proposed by the focus group</i>
15	OFFs are more concerned about the rights and obligations for freight damage claims.	Lin and Liang (2011)
16	OFFs track CLSs' operation dynamics more in detail.	Proposed by the focus group
17	The liaison burden between OFFs and CSLs decreases.	Lu (2013)
18	The complexity of shipment consolidation increases.	Burkovskis (2008); Lin and Liang (2011)

CSL, container shipping lines; OFF, ocean freight forwarder.

Table 2. Triangular fuzzy numbers and membership function for linguistic variables

Linguistic variables for importance	Triangular fuzzy numbers	Membership function
Extremely disagree (ED)	(0, 0, 0.2)	
Very disagree (VD)	(0, 0.2, 0.4)	
Disagree (D)	(0.1, 0.3, 0.5)	
Moderate (M)	(0.3, 0.5, 0.7)	
Agree (A)	(0.5, 0.7, 0.9)	
Very disagree (VA)	(0.6, 0.8, 1)	
Extremely agree (EA)	(0.8, 1, 1)	

The questionnaire asked respondents to express the agreement in perceived recognition from their practical experience for each factor. A 7-point scale of linguistic variables, from 1 for extremely disagree to 7 for extremely agree, were applied to measure respondent opinions. Table 2 shows the settings of triangular fuzzy numbers for every linguistic variable and their membership function.

3.2.2 Sampling

The questionnaires of formal investigation were preset to distribute to 50 freight forwarders in Taiwan from January to March 2018. This study used snow-ball sampling to construct the invested panel by introducing respondents one by many. Most of them were the board of directors and supervisors of the International OFF League at Taipei (IOFFLAT). However, the recommendable conditions were advised in every introducing linkage. The main conditions included that the respondents' served companies must have already acquired the certification of AEO and be the required business markets, i.e., short sea, deep ocean, or both. These respondents serve companies that belong to the 741 members in this league that share more than 85% of OFFs in Taiwan. This panel consists of diversified features considering the balance on personal background and experience and service scales and scopes of their serving companies.

All respondents returned their opinions, and every questionnaire was effective. Respondents over 40 years old responded to more than 60%, almost the exact percentages for work experience greater than 16 years. The main business markets for deep ocean or short sea services were even at 40%. The remainder 20% focused on both markets. More than 50% of respondents were titled manager. The ratio of respondents serving companies with 15 years or greater was 68%. Table 3 shows the backgrounds of sampling respondents. This sampling revealed high reliability with Cronbach's α value of 0.834 and a good validity in the Bartlett test with KMO statistics of 0.74 for the questionnaire, respectively.

Table 3. Structure of sampling respondents

Sample characteristics	Groups	Effective samples	Group shares (%)	Cumulative percentage (%)
Age	21 to 30	9	18.0	18.0
	31 to 40	10	20.0	38.0
	41 to 50	17	34.0	72.0
	51 to 60	10	20.0	92.0
	Above 60	4	8.0	100.0
Work experience (years)	Below 5	7	14.0	14.0
	6 to 10	9	18.0	32.0

Work experience (years)	11 to 15	3	6.0	38.0
	16 to 20	8	16.0	54.0
	21 to 25	14	28.0	82.0
	Above 26	9	18.0	100.0
Main business market	Deep ocean	20	40.0	40.0
	Short sea	21	42.0	82.0
	Both in even	9	18.0	100.0
Title	Top manager	10	20.0	20.0
	Middle manager	18	36.0	56.0
	OP/CS staff	15	30.0	86.0
	Sales	4	8.0	94.0
	Document staff	3	6.0	100.0
Company history (years)	Below 5	5	10.0	10.0
	6 to 10	6	12.0	22.0
	11 to 15	5	10.0	32.0
	16 to 20	6	12.0	44.0
	21 to 25	3	6.0	50.0
	Above 26 years	25	50.0	100.0

4. Similarity Aggregation Method (SAM) Analysis

The results of descriptive statistics provide a preliminary concept for this investigation. This section uses SAM to aggregate the consensus of opinions from all respondents based on the settings of their conditions, such as work experience, main business markets managed, and job titles.

4.1 Results for All Experts

The given value of β in Equation (7) is a critical setting to distinguish the individual weights for respondents. While $\beta = 0$ means the RAD is considered only without taking the relative weights of each respondent's importance levels (w_i), i.e., $CDC = RAD$. This section first reports the case of $\beta = 0$ to neglect the different individual conditions of all respondents. Table 4 shows that the linguistic expression for every respondent opinion was first transformed into the system of triangular fuzzy numbers.

Following the steps of SAM operation, we constructed eighteen 50×50 matrixes of agreement degrees for every factor. Each S_{ij} follows equation (3) calculation to complete the mutual consensus evaluation for respondents. Then, the AAD ($A(E_i)$), RAD, and CDC for each respondent can be calculated as Equations

Table 4. Calculated indexes for the 1st question item while $\beta = 0$

Sample (<i>i</i>)	$A(E)$	RAD_i	CDC_i	Sample (<i>i</i>)	$A(E)$	RAD_i	CDC_i
1	0.618076	0.027610	0.027610	26	0.618076	0.027610	0.027610
2	0.618076	0.027610	0.027610	27	0.618076	0.027610	0.027610
3	0.618076	0.027610	0.027610	28	0.268598	0.011999	0.011999
4	0.618076	0.027610	0.027610	29	0.618076	0.027610	0.027610
5	0.268598	0.011999	0.011999	30	0.618076	0.027610	0.027610
6	0.618076	0.027610	0.027610	31	0.268598	0.011999	0.011999
7	0.618076	0.027610	0.027610	32	0.315242	0.014082	0.014082
8	0.315242	0.014082	0.014082	33	0.618076	0.027610	0.027610
9	0.268598	0.011999	0.011999	34	0.268598	0.011999	0.011999
10	0.618076	0.027610	0.027610	35	0.618076	0.027610	0.027610
11	0.618076	0.027610	0.027610	36	0.148688	0.006642	0.006642
12	0.148688	0.006642	0.006642	37	0.268598	0.011999	0.011999
13	0.618076	0.027610	0.027610	38	0.618076	0.027610	0.027610
14	0.268598	0.011999	0.011999	39	0.618076	0.027610	0.027610
15	0.618076	0.027610	0.027610	40	0.618076	0.027610	0.027610
16	0.148688	0.006642	0.006642	41	0.045253	0.002022	0.002022
17	0.618076	0.027610	0.027610	42	0.315242	0.014082	0.014082
18	0.148688	0.006642	0.006642	43	0.618076	0.027610	0.027610
19	0.618076	0.027610	0.027610	44	0.148688	0.006642	0.006642
20	0.315242	0.014082	0.014082	45	0.618076	0.027610	0.027610
21	0.618076	0.027610	0.027610	45	0.268598	0.011999	0.011999
22	0.268598	0.011999	0.011999	47	0.148688	0.006642	0.006642
23	0.618076	0.027610	0.027610	48	0.618076	0.027610	0.027610
24	0.618076	0.027610	0.027610	49	0.148688	0.006642	0.006642
25	0.618076	0.027610	0.027610	50	0.315242	0.014082	0.014082

RAD , relative agreement degree; CDC , consensus degree coefficient.

(4), (5), and (7). For example, Table 5 illustrates the calculation results for question item 1. Considering the fuzzy opinions of all respondents, the aggregation result, following as Equation (8), $\tilde{R} = (0.467452, 0.667452, 0.867048)$ for question item 1.

The same steps were conducted for other question items. Table 5 collects all aggregation results of every question item and their defuzzification for ranking results. Items 11 to 16, with defuzzification values over 0.7, were clustered as an

item group with significant changes.

4.2 Analysis to Append Expert Weights

For exploring the possibility of different results from individual conditions, this study set the relative weights with a variety of respondent identities. The analysis categories included their work experience, main managing business markets, and job titles. The given relative weights were set from 1 to the number of the investigated group. Table 5 shows that the greater the importance of the respondent group, the larger the setting weight. It was noted that the influence of the shipping lines industry occurred more for deep ocean services than for short sea markets because of growing ship sizes. The relative weights of businesses markets were set as larger as the scope of respondent management of the deep ocean. After a normalization process of the given weights, each respondent has a given relative weight of the importance (r_i) in carrying on the SAM operations.

As equation (6), every respondent's important degree (w_i) can be calculated. Further, let $\beta = 0.5$ express a neutral preference so that the required processes in SAM can be implemented. Table 6 shows the example for all indexes of the first question item that has been weighted by work experience for all respondents.

Table 7 shows the results using the same operation of SAM for three kinds

Table 5. Weight settings for different individual background

Analysis category	Group	Samples	Given weights	Sum of weights	Weights of normalization
Work experience	Below 5 years	7	1	21	0.0476
	6 to 10 years	9	2		0.0952
	11 to 15 years	3	3		0.1429
	16 to 20 years	8	4		0.1905
	21 to 25 years	14	5		0.2381
	Above 26 years	9	6		0.2857
Main business markets	Short sea	21	1	6	0.1667
	Deep ocean	20	3		0.5000
	Both in even	9	2		0.3333
Title	Top manager	10	5	15	0.3333
	Middle manager	18	4		0.2667
	OP/CS staff	15	3		0.2000
	Sales	4	2		0.1333
	Document staff	3	1		0.0667

Table 6. Calculated indexes with work experience for the 1st question item

Sam- ple (<i>i</i>)	$A(E)$	RAD_i	w_i	CDC_i	Sam- ple (<i>i</i>)	$A(E)$	RAD_i	w_i	CDC_i
1	0.618076	0.027610	0.026316	0.026963	26	0.618076	0.027610	0.010526	0.019068
2	0.618076	0.027610	0.026316	0.026963	27	0.618076	0.027610	0.015789	0.021700
3	0.618076	0.027610	0.026316	0.026963	28	0.268598	0.011999	0.026316	0.019157
4	0.618076	0.027610	0.031579	0.029595	29	0.618076	0.027610	0.005263	0.016437
5	0.268598	0.011999	0.031579	0.021789	30	0.618076	0.027610	0.015789	0.021700
6	0.618076	0.027610	0.026316	0.026963	31	0.268598	0.011999	0.005263	0.008631
7	0.618076	0.027610	0.026316	0.026963	32	0.315242	0.014082	0.010526	0.012304
8	0.315242	0.014082	0.026316	0.020199	33	0.618076	0.027610	0.026316	0.026963
9	0.268598	0.011999	0.026316	0.019157	34	0.268598	0.011999	0.005263	0.008631
10	0.618076	0.027610	0.026316	0.026963	35	0.618076	0.027610	0.010526	0.019068
11	0.618076	0.027610	0.021053	0.024331	36	0.148688	0.006642	0.010526	0.008584
12	0.148688	0.006642	0.026316	0.016479	37	0.268598	0.011999	0.021053	0.016526
13	0.618076	0.027610	0.021053	0.024331	38	0.618076	0.027610	0.015789	0.021700
14	0.268598	0.011999	0.021053	0.016526	39	0.618076	0.027610	0.005263	0.016437
15	0.618076	0.027610	0.026316	0.026963	40	0.618076	0.027610	0.005263	0.016437
16	0.148688	0.006642	0.026316	0.016479	41	0.045253	0.002022	0.031579	0.016800
17	0.618076	0.027610	0.031579	0.029595	42	0.315242	0.014082	0.031579	0.022831
18	0.148688	0.006642	0.031579	0.019111	43	0.618076	0.027610	0.031579	0.029595
19	0.618076	0.027610	0.026316	0.026963	44	0.148688	0.006642	0.010526	0.008584
20	0.315242	0.014082	0.021053	0.017567	45	0.618076	0.027610	0.031579	0.029595
21	0.618076	0.027610	0.031579	0.029595	45	0.268598	0.011999	0.010526	0.011262
22	0.268598	0.011999	0.021053	0.016526	47	0.148688	0.006642	0.021053	0.013847
23	0.618076	0.027610	0.021053	0.024331	48	0.618076	0.027610	0.010526	0.019068
24	0.618076	0.027610	0.005263	0.016437	49	0.148688	0.006642	0.010526	0.008584
25	0.618076	0.027610	0.010526	0.019068	50	0.315242	0.014082	0.005263	0.009673

RAD , relative agreement degree; CDC , consensus degree coefficient.

of weighted categories. The defuzzification figures slightly differ, but the ranks of the top seven and question items 4, 8, and 17 for the three types of weighting schemes are the same. For comparison with the result of setting $\beta = 0$ in Table 6, the sequence of the top three factors is presented differently. The weighting schemes for different individual background conditions of respondents slightly altered the evaluation results to obtain a more distinguished and reliable group consensus. After the industrial change of upstream, OFFs cared more about their rights

and obligations when damage claims occurred. The dynamics of operation details from the changes of carriers attracted OFFs more attention. Meanwhile, such enormous variation from upstream actually generated more significant pressure on the freight businesses to OFFs. This result might be why OFFs experienced no reduction in liaison burden with their cooperated CSLs.

4.3 Discussion

From the investigation summary, the variation of industrial structure among CSLs generated influences for OFFs. Several factors were ranked higher in the consensus, belonged to inner awareness, and were event-driven. The sudden broken-down announcement from the Hanjin Lines caused onboard containers detained on its ships because they were prohibited from sailing into harbors. Port administrators and operators worried this company could no longer pay off port tariffs and charges. Panicked shippers were confronted with a complex situation in which their cargo could not be delivered to fulfill the trade contract and could not perform redelivery by other shipping lines. There is only one solution that shippers can use to claim compensation for their consigned forwarders with this event. In the same situation, OFFs also play a role as shippers to carriers; their rights are also hampered by bankruptcy, which falls on freight forwarders. OFFs might have related knowledge on handling this situation, but they cannot do anything about it because they are inexperienced. Involuntarily, freight forwarders must pay greater attention to the rights and obligations regarding cargo damage claims as part of their processes. OFFs are often willing to avoid such things and wish never to have them happen again by reminding employees to observe the details of the operational dynamics of CSLs closely. Such experiences induce OFFs to care more about risk management than before.

The hidden factor of continuous growth of containership sizes puts more significant pressure on CSLs to maximize their capacity as cost-saving is measured as unit transportation for containers. These targets were also transferred to cooperating OFFs before the close date for each stop of mega-ship voyages. This pressure was also passed on from online forwarders of larger ships to off-line OFFs like a cascading effect, which led OFFs to uncertainty and hesitancy on ship slot control. Also, the changes of port call for routes because larger ships or strategic alliance deployment might result in the alternation of shippers' logistical chains and will exert OFFs pressure to rapidly respond to the changes of logistical decision making from shippers. OFFs might require rerouting seaborne and inland transports for shippers at those ports without mega-ship calls. Any additional charges in a new routing operation, such as truck fees and stevedoring charges, may appear different. A large scale of port rotation alternation and service network change because of cascading effects of mega-ships or the reshuffling of SAs, at the same time, might influence the freight rates that CSLs offered to OFFs.

Table 8. Comparison of defuzzification results between different weighting measures

Question Item	Weighted by work experience				Weighted by business market				Weighted by job title			
	$\bar{R} = (a, b, c)$			Rank	$\bar{R} = (a, b, c)$			Rank	$\bar{R} = (a, b, c)$			Rank
	a	b	c		a	b	c		a	b	c	
1	0.443989	0.648989	0.845629	7	0.446647	0.646647	0.845322	7	0.446086	0.646086	0.843636	7
2	0.438884	0.635766	0.825442	8	0.421550	0.619237	0.808346	11	0.426044	0.624294	0.814525	9
3	0.330201	0.530201	0.722462	16	0.332026	0.532026	0.722210	17	0.328655	0.528655	0.719401	15
4	0.361047	0.558855	0.751834	13	0.362245	0.559911	0.756958	13	0.353818	0.551484	0.746284	13
5	0.424344	0.623224	0.813943	9	0.440758	0.638443	0.829192	8	0.426151	0.624398	0.816832	8
6	0.412863	0.611762	0.805426	11	0.433117	0.630821	0.822481	10	0.423567	0.621833	0.814054	11
7	0.423020	0.621889	0.796375	10	0.440527	0.638202	0.813799	9	0.426201	0.624438	0.802282	10
8	0.363439	0.562288	0.761560	12	0.380376	0.578031	0.775582	12	0.368016	0.566233	0.764346	12
9	0.337648	0.529217	0.728005	15	0.356613	0.551056	0.747526	14	0.341164	0.533921	0.732076	14
10	0.326243	0.525088	0.722813	17	0.334641	0.532291	0.728751	16	0.327056	0.525268	0.722852	16
11	0.550216	0.750216	0.911409	5	0.550583	0.750583	0.909689	5	0.549459	0.749459	0.910812	5
12	0.537461	0.737461	0.909646	6	0.541739	0.741739	0.903872	6	0.531065	0.731065	0.902748	6
13	0.564071	0.764071	0.901942	3	0.582197	0.782197	0.913799	3	0.573489	0.773489	0.905653	3
14	0.553827	0.753827	0.919623	4	0.557549	0.757549	0.921400	4	0.558954	0.758954	0.922805	4
15	0.594548	0.794548	0.937778	1	0.594790	0.794790	0.936560	1	0.594790	0.794790	0.937122	1
16	0.588041	0.788041	0.940094	2	0.592059	0.792059	0.941144	2	0.589250	0.789250	0.941706	2
17	0.302881	0.502881	0.697505	18	0.282455	0.482455	0.678445	18	0.293691	0.493691	0.689119	18
18	0.336403	0.534313	0.723568	14	0.340268	0.536386	0.724547	15	0.328470	0.524588	0.713873	17

As information and communication technologies progressed, industrial re-structure made carriers emphasize the use and development of modern information techniques, such as the appearance of blockchain technology. The cooperation among runners and other stakeholders or even transaction platform providers, such as Alibaba, let OFFs alter e-commerce applications' perception. This development is the channel through which OFFs can observe the detailed operation dynamics. In Taiwan, some OFFs even build up a transaction platform to enforce the integration capabilities of freight consolidation in advance. The function of e-commerce has developed to maximization of logistics integration.

Noted that carrier services on transport reliability and quality did not worsen because of reduced CSLs or reshuffling SA members. The brand confidence of existing CSLs did not slack to OFFs. OFFs did not detect the consolidated operations becoming more complicated than before. However, OFFs were still required to keep intensive relationships with shipping lines. The connections to complement one another between OFFs and carriers were not changed.

Although the survey results contributed from the sampling to the 50 respondents of OFFs in Taiwan, recent rapid and considerable changes in the global supply chain support the robustness of the main findings summarized in this study. The recent case that a giant containership named 'EVER GIVEN' blocked the Suez Canal and resulted in the largest general average claim in global maritime history (<https://theloadstar.com/>). This event deepens global OFFs risk recognitions for their relationships with CSLs. The outbreak of the COVID-19 pandemic made a severe shortage of ship slots and empty containers because of worsened logistical speed and lengthened cycle time for load equipment of CSLs (<https://home.kuehne-nagel.com/>). Slot control and reservation became the best advantage of OFFs to attract their businesses despite shippers being aware of extraordinarily forwarding handlings.

Stakeholders in the container transportation chain launched the new digital logistics platform for providing customers with instant online cargo booking and tracking (<https://container-news.com/>). Such development puts forwarders or NOVCCs a heavy erodent pressure on their businesses. Global logistical integrators vigorously appeal to customers to use their networks for a suitable choice of transportation alternatives with lower risk (<https://home.kuehne-nagel.com/>). This tendency also expresses the importance of e-commerce platforms for OFFs in future operations.

Although the phenomena above are accompanied by special events occurring, the significant relationships with the structural variation of the CSL industry are apparent. However, transport reliability and quality in ocean container deliveries almost collapsed because of the unstoppable COVID-19 pandemic. Port congestion stalling the regular cycle times of ships and containers induced the extraordinary soaring of freight rates (<https://www.lloydsloadinglist.com/>). These event-driven influences are unexpected after the structural variation of the CSL industry.

5. Conclusion and Suggestion

Driven by the progress of growing containership sizes, the whole industry of CSLs has confronted a grim challenge during this last decade. The degree of industrial centralization gradually increased, while some CSLs with unhealthy financial status withdrew, more mergers and acquisitions occurred, and global SAs reorganized again. This study explored the influence of OFFs, the vital partners of CSLs, and the enormous variation of industrial structure and environment among CSLs. For clarifying the key factors that influence OFFs' operation and management and crucial concerns in their decisions, this study has proposed 18 question items based on a literature review and in-depth expert interviews. Questionnaires with seven rating levels for recognition agreement were distributed to 50 experts who served in various OFF companies.

The investigation results revealed that most question items approached at an agreed level. The analysis results of SAM, based on fuzzy operation techniques, ensure that the experience of facing a sudden bankruptcy of a shipping line increased OFFs awareness on the rights and obligations for freight damage claims. OFFs enforced risk management, in particular, to track the operation dynamics of shipping lines. The event of 'EVER GIVEN' has sufficiently reflected the same worries from OFFs and shippers as found in this study.

Among all ordinary operation practices, OFFs felt the competitive pressure of freight consignment. Quotations of freight rates from shipping lines seem to be more changed than before. Fast cooperation steps between shipping lines and transaction platform providers resulted in the changes of OFFs' perception towards e-commerce. The alternation of port calls on service routes made OFFs quickly respond to shippers' logistical requirements changes. However, shipment consolidation seems not to have become more complicated than before. The service qualities, brand confidence, transport reliabilities, and cooperated relationships with CSLs did not worsen for OFFs, although the number of CSLs decreased.

This study investigated and understood how industrial restructuring consequences from CSLs affected OFFs along the container shipping chain. OFFs can keep attention on the risk management to prevent another wave just in another case. Any stakeholder should be reluctant to be seriously affected because of the ripple from other industries. The industry of CSLs can also learn the concerned scruples affected OFFs from this study. If the whole society of CSLs would like to take the responsibility to avoid the extensive effects of industrial restructures to the downstream stakeholders, this study provides a valuable reference for the OFFs' recognition.

These changes among CSLs also bring alternation to other partners, such as port operators and inland transportation partners, which can be further studied. The severe outbreak of Covid-19 at the beginning of 2020 brings another unprecedented influence on the global transportation industry. From the findings of this

study, OFFs might be ready to confront the effects of an extraordinary impact on CSLs. OFFs might temporarily enjoy a short-term benefit because of increasing freight rates, while CSLs temporarily encounter considerable decreases in transportation demand. The influence and effect of pandemics spreading towards CSLs, OFFs, and other stakeholders along shipping value chains should be an inevitable and timely topic for further study.

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Effect of Abnormal Earnings on Earnings Persistence: The Case of Shipping and Shipbuilding Industry

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ABSTRACT

Even though shipping and shipbuilding industries have been one of the leading industries in Korea, both industries have been suffered a long dark period since the global financial crisis 2008. In particular, since both industries are more sensitive to economic fluctuations than other industries, stable earnings are an important factor in stakeholders' economic decision-making. This study investigates the difference of earnings persistence between shipping and shipbuilding industry using Ohlson's model. Empirical results show that earnings persistence of shipbuilding industry is significantly higher than that of shipping industry. This result implies that the low earnings persistence of the shipping industry result from the global economic recession after the 2008 global financial crisis and government policies focused on the shipbuilding industry. On the other hand, the high earnings persistence of the shipbuilding industry can be attributed to high added value ship orders, intensive support from the government and economies of scale after the global financial crisis. In the case of the shipbuilding industry, high technology and ship quality are important factors for high earnings creation while in the shipping industry, intangible factors such as cargo service quality, route, and creditworthiness of cargo transportation are important factors for continuous earnings creation. In addition, the balance of government policies on the shipping and shipbuilding industries is expected to bring about shared growth between the two main industries in Korea.

Key words : abnormal earnings, earnings persistence coefficient, shipping and shipbuilding industry

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1. Introduction

The shipping and the shipbuilding industry have been Korea's core industries since the 1970's and have strong relationship between the forward and backward in the value chain. Both industries have been suffered a long dark period since the global financial crisis 2008, and Hanjin Shipping, Korea's largest shipping firm, went bankrupt in 2017. In addition, the two major Korean shipbuilders, Daewoo Shipbuilding & Marine Engineering (DSME) and Hyundai Heavy Industries (HHI), are also pursuing a Merge and Acquisitions (M&As).

This study investigates whether there is a difference in the earnings persistence as a proxy of earnings quality between shipping and shipbuilding industries. After the global financial crisis in 2008, the usefulness of accounting information has greatly increased due to the bankruptcy and M&A of Korean shipping and shipbuilding industries. In addition, as the global economic downturn caused by COVID-19 continues, earnings persistence, which can measure the viability of firms, is recognized as an important indicator for investors. Earnings persistence is an objective indicator that can provide useful information for economic decision-making to stakeholders related to a firm and measure the firm's sustainable growth and management rationalization. This study aims to systematically measure valuation of the firm using the persistence of accounting profits presented in the Ohlson model (1995). The outstanding feature of the Ohlson model is that even though the earnings calculation process and accounting method are different for each firm, it is not affected by the valuation method.

Major users of accounting information in Korea (financial analysts, credit rating agencies, and CPA etc.) consider the earnings quality as most useful factor when evaluating firms (Choi et al., 2019). In particular, financial analysts assess that earnings persistence is the most important indicator of valuation of firm. In addition, many previous studies (Ali et al., 2007; An, 2017; Sloan, 1996) suggest that the higher the earnings persistence, the better the quality of earnings, which is useful for firm's investment decision-making. In addition, the higher the earnings persistence, the greater the share price explanatory power of accounting earnings (Dechow and Dichev, 2002; Francis et al., 2004; Sloan, 1996). In particular, after the introduction of International Financial Reporting Standards (IFRS), it appears that users of accounting information actively use the concept of earnings quality in practice (Park, 2018). This study expects to contribute to literature and practice on shipping and shipbuilding industries in several ways. First, ample previous studies find earnings persistence provides useful information for firm valuation and M&As. Therefore, this study provides a rational investment decision based on the intrinsic value of the shipping and shipbuilding industries. Second, considering the recent rapidly changing global economic environment, stable earnings are very important for a firm's continuous growth and going-concern. In particular, the shipping and shipbuilding industries are sensitive to economic fluctuations, thus earnings persistence is an important indicator for stakeholders. Despite the importance of the

shipping and shipbuilding industries, previous studies have addressed the earnings persistence in manufacturing industry, construction industry (Paek and Yoo, 2012), family firms (Boonlert-U-Thai and Sen, 2019) or financial distress firms (Shin, 2005). Thus, this study expands empirical evidence of earnings persistence for shipping and shipbuilding industries. Finally, this study proposes the implication of government policy for Korean shipping and shipbuilding industry. Although both industries account for an important role in the Korean economy, it is considered that the government's discriminatory policy support is being applied (An, 2020; KMI, 2017). In addition, the shipping industry shows better performances than other industries when the economy improves, but the risk management should be required when the economy deteriorates (Kim, 2014). For the mutual growth of shipping and shipbuilding, it is necessary to consider the consistency and the equity of support of government policies. Therefore, this study provides good implications for the government to reconstruct Korea's shipping and shipbuilding industries as leading industries in the Korean economy.

The reminder of this paper is organized as follows. Chapter 2 outlines previous researches and proposes research questions. In Chapter 3, sample selection procedure and research methodology are explained. The empirical results are presented in Chapter 4. The summary of the research and suggestions of further research appear in Chapter 5.

2. Literature Review

2.1 Earnings Persistence

The purpose of financial statements should provide useful information to users in making economic decision, thereby making a difference to their decisions. Dechow (1994) insists that earnings are very important for a large variety of stakeholders because of providing information of firm performance. Investors and managers use earnings as one of the main guides to identify and evaluate investment opportunities (Bushman and Smith, 2003). Schipper and Vincent (2003) propose that earnings persistence is derived from a decision usefulness perspective.

Jonas and Blanchet (2000) emphasize that earnings persistence is specifically based on the user needs. Financial reporting users view highly persistent earnings as sustainable which means more permanent and less transitory. Richardson et al. (2005, p.20) define earnings quality as earnings persistence, which means “*degree to which earnings performance persists into the next period.*” Benish and Vargus (2002, p.756) state that “*the quality of current earnings is the likelihood that the current earnings are sustainable in the future.*” Accordingly, a highly persistent earnings number is viewed by investors as sustainable, that is, recurring, more permanent and less transitory, and therefore higher quality (Penman and Zhang, 2002; Schipper and Vincent, 2003).

By applying the concept of earnings persistence to the firm valuation model, future earnings affect the firm's valuation, but short-term earnings do not significantly affect the firm value. The most important factor in the decision of analysts selecting investment stocks, determining the transaction price during M&As, and the initial public offering price of new stocks is the rational measurement of firm value. There are many ways to measure a firm's value, but the most common is to predict future earnings and discount them using appropriate discounted ratio. At this time, the most important thing is to analyze past or present earnings to find the elements of earnings that are expected to continue in the future. Therefore, it can be seen that the persistence of earnings plays the most important role in terms of firm valuation.

Lev and Thiagarajan (1993) suggest 12 basic factors necessary for firm valuation. These basic factors are very important in evaluating the persistence of earnings, and the earnings quality is the same concept as earnings persistence. In particular, from the point of view of analysts who are interested in firm valuation, earnings persistence is the most appropriate concept to evaluate firm value. Moreover, when the quality of earnings reflects the persistence or growth potential of earnings, a firm with high earnings quality is considered to have higher earnings persistence in the future.

Bricker et al. (1995) find that analysts emphasize core earnings in analyzing firm's value, and that they recognize predictable earnings that occur repeatedly and consistently as a core earnings. This suggests that the higher the earnings persistence, the higher the predictability of earnings and the lower the volatility of earnings. Dechow and Dichev (2002) argue that the higher the persistence of a firm's earnings, the higher the quality of its earnings. Therefore, firms with high earnings persistence can predict future performance more usefully through current earnings compared to firms with low earnings persistence.

Kim et al. (1998) reported that the earnings persistence coefficient of Korean manufacturing industry ranges from 0.196 to 0.537 by year using Ohlson's model (1995). Paek and Yoo (2012) investigated the earnings persistence in the construction industry using the autocorrelation coefficient of earnings in two consecutive periods. The earnings persistence coefficient of the construction industry was 0.741, which is higher than that of other industries. More recently, Jung and Paek (2016) investigated the earnings persistence of Korean manufacturing industry from 1985 to 2010 in the same way as Paek and Yoo (2012). The earnings persistence coefficient ranged from -0.114 to 1.336, with an average value of 0.574. According to previous studies, although earnings persistence is an important indicator for evaluating firm value, previous studies have been conducted to analyze earnings persistence in the manufacturing industries not shipping and shipbuilding industries. This study investigates the earnings persistence of the shipping and shipbuilding industries, which are affected by environmental factors and economic fluctuations. Instead of establishing explicit hypotheses, this study intends to examine the persistence of earnings by dividing the samples of the two industries in detail.

2.2 Ohlson Model

The Ohlson model (1995) is based on the assumptions about the clean surplus relationship of net assets as follows in equation (1).

$$BV_t = BV_{t-1} - E_t - D_t \quad (1)$$

where, for period t

BV = net assets, E = net income, D = dividend after adjusting paid-in-capital

By connecting the clean surplus relation of BV in equation (1) with the discounted dividend model, the enterprise value (V) can be expressed as a function of BV and excess earnings (XE) as shown in equation (2).

$$V_t = BV_t + \sum_{n=1}^{\infty} (1+r)^{-n} E[XE_{t+n}] \quad (2)$$

where, for period t

r = cost of capital, $E[.]$ = sign of expected value, XE_{t+n} = abnormal earnings for year $t+n$

According to Ohlson's model, the value relevance of BV or net income is explained through the earnings persistence coefficient of abnormal earnings. In Ohlson's model, the earnings persistence coefficient (φ) of abnormal earnings is defined as the first autoregressive process of abnormal earnings as follows.

$$\begin{aligned} XE_{t+1} &= \varphi XE_t + O_t - \varepsilon_{1t+1} \\ O_{t+1} &= \delta O_t + \varepsilon_{2t+1} \end{aligned} \quad (3)$$

where, for period t

O = Other information other than abnormal earnings,

φ and δ is autoregressive coefficients of XE and O , ε_{1t+1} and ε_{2t+1} are error terms.

Since it is assumed that the abnormal earnings (XE_t) gradually decrease due to competition among firms, the stochastic process of the abnormal earnings can be expressed as the following autoregressive process.

$$[0 \leq \varphi \leq 1, E(e_1 + t + 1) = 0] \quad (4)$$

3. Research Methodology

3.1 Sample Selection

This study uses shipping and shipbuilding firms listed on the Korean Stock Exchange (KRX) for sixteen-year (2000–2015). Data Analysis, Retrieval and Transfer System (DART) and KIS-Value databases are used for data required for the estimation of the earnings persistence coefficients.

In order to reduce the effect of outliers, this study winsorizes firms whose mean value differences in BV , net income, and persistence coefficient variables exceed three times the standard deviation. The final sample includes 95 firm-year observations of shipping firms and 78 firm-year observations of shipbuilding firms over the sixteen-year periods.

3.2 Empirical Model

As a first stage, this study estimates the earnings persistence coefficient (φ) using the Ohlson model (1995) to measure the persistence of abnormal earnings against BV and accounting earnings. The Ohlson model is based on assumptions about the clean surplus relation. For the Ohlson model's abnormal earnings, the earnings persistence coefficient estimated from the firm-specific time series data is used. The autocorrelation coefficient of abnormal earnings over two consecutive periods is estimated for each firm presented in equation (5). In addition, equation (5) is estimated using time series data for the last 16 years for each shipping and shipbuilding firm.

$$E_t - rBV_{t-1} = \varphi E_{t-1} - rBV_{t-2} + \varepsilon_{i,t} \quad (5)$$

where for year t ,

E is net income BV is net asset, $E_t - rBV_{t-1}$ is abnormal earnings

Equation (5) shows that future abnormal earnings ($E_t - rBV_{t-1}$) follow a time series, and earnings persistence coefficient (φ) has several meanings. The earnings persistence coefficient (φ) has generally a value between 0 and 1. When $\varphi = 0$, the firm is in a state of no development while when $0 < \varphi < 1$, the firm's return on equity (ROE ; return on capital investment) shows a mean reverting tendency that approaches the firm's cost of capital (Bernard, 1994; Freeman et al., 1982). Therefore, for the empirical analysis of this study, it is important to know what the current excess abnormal earnings are and how consistent these excess abnormal earnings are. That is, it is important to estimate the magnitude of φ .

At second stage, this study estimates the autocorrelation relationship between the future earnings and the current earnings to find whether the earnings

persistence coefficient plays a role as a partitioning variable using equation (6). Earnings persistence indicates how much of current earnings will persist into the future and continue from period to period. In equation (6), earnings persistence is measured as the slope-coefficient estimates employed by Ali et al. (2007) and Sloan (1996).

$$Earnings_{t+1} = \alpha_0 + \beta_1 Earnings_t + \varepsilon_t \quad (6)$$

where for year t , and $Earnings_t$ is earnings per share (EPS) in year $t+1$; $Earnings_{t-1}$ is EPS in year $t-1$; ε_t is the residual error;

Value of β_1 close to one implies highly persistence earnings, while value of β_1 close to zero indicates highly transitory earnings. High quality earnings are persistent, recognized by financial statement users as sustainable, less transitory, and more permanent (Richardson, 2005; Sloan, 1996). Therefore, large (small) values of the slope-coefficient (β_1) correspond to more (less) persistence.

4. Empirical Results

4.1 Descriptive Statistics

Table 1 shows descriptive statistics for earnings components of both shipping and shipbuilding industry. The mean and median value of BV of shipping industry are 831,000 million KRW and 569,000 million KRW, while those of shipbuilding industry are 3,390,000 million KRW and 1,960,000 million KRW, respectively. This shows that the size of the shipbuilding industry is more than three times that of the shipping industry. Average net income (E) of shipping industry shows negative (−35,500 million KRW), but that of shipbuilding industry is positive (220,000 million KRW). The average EPS of the shipping industry is −2,893 KRW, while the shipbuilding industry is 4,031 KRW, indicating that the profitability of the shipping industry is low.

The mean of ROE for both industries is negative, and average leverage ratio (LEV) of both industries is similar at 3.838 and 3.463, respectively. The mean (median) value of return on sales (ROS) of the shipping industry is 0.007 (0.024), while that of the shipbuilding industry is 0.025 (0.028).

The average ROS of the shipping industry is 0.007, meaning that net income accounts for only 0.7% of total sales, suggesting that the shipping industry has low profitability. The average ROS of the shipbuilding industry is 0.025, indicating better profitability than the shipping industry. The mean of LEV of both shipping and shipbuilding industries is 3.83 and 3.46, indicating that both industries are highly dependent on debt.

Table 1. Descriptive statistics

Shipping industry					
	Mean	Median	Max.	Min.	Std. Dev.
<i>BV (million)</i>	831,000	569,000	3,000,000	-171,000	846,000
<i>E (million)</i>	-35,500	11,700	786,000	-1,910,000	381,000
<i>EPS</i>	-2,893.719	164.00	51,371.00	-228,113.00	29,447.18
<i>ROE</i>	-0.217	0.093	12.098	-26.613	3.158
<i>ROS</i>	0.007	0.024	0.717	-1.547	0.221
<i>LEV</i>	3.835	3.054	68.164	-198.559	24.427
Shipbuilding industry					
	Mean	Median	Max.	Min.	Std. Dev.
<i>BV (million)</i>	3,390,000	1,960,000	19,000,000	120,000	4,480,000
<i>E (million)</i>	220,000	64,600	4,560,000	-3,310,000	957,000
<i>EPS</i>	4,031.325	718.500	75,808.00	-32,296.00	14,992.21
<i>ROE</i>	-0.023	0.108	0.386	-7.567	0.878
<i>ROS</i>	0.025	0.028	0.186	-0.220	0.061
<i>LEV</i>	3.463	2.876	42.658	1.212	4.665

BV, net assets; *E*, net income; *EPS*, earnings per share; *ROE*, E/BV; *ROS*, return on sales; *LEV*, total liability/net assets.

4.2 Core Results

Table 2 compares difference in the estimated abnormal earnings persistence coefficient between the shipping industry and the shipbuilding industry. The abnormal earnings persistence coefficient (ϕ) of the shipping industry is 0.165. It means that the effect of 100 KRW in excess earnings in year t on excess earnings in year $t+1$ is about 16 KRW in the shipping industry. On the other hand, the estimated abnormal earnings persistence coefficient of the shipbuilding industry is 0.592, which is more than three times the excess earnings of the shipping industry. This result suggests that the earnings persistence of the shipbuilding industry is higher than that of the shipping industry in the relationship between the earnings of 1 KRW for the current period and the earnings of the next year. In addition, this indicates that the profitability of the shipbuilding industry is more stable than that of the shipping industry.

The low earnings persistence coefficient of the shipping industry indicates that Korea's shipping industry has low added value despite the world's fifth largest volume. The earnings of shipping business occur in various areas, such as ship investment, ship operation, shipping brokerage, and ship management. However, in Korea's shipping industry, most of the earnings mainly depend on ship operating income from shippers but the earnings of other fields are still at a low level (KMI,

Table 2. Estimated abnormal earnings persistence coefficient between shipping and shipbuilding industry

$E_t - rBV_{t-1} = \varphi E_{t-1} - rBV_{t-2} + \varepsilon_{i,t}$		
Variables	Shipping industry	Shipbuilding industry
	Coefficient (<i>t</i> -value)	Coefficient (<i>t</i> -value)
<i>Constant</i>	0.0079 (0.333)	0.0058 (0.624)
φ	0.165 (1.923)*	0.592 (3.672)***
<i>Adj R</i> ²	0.045*	0.176***
<i>F</i> -Statistics	3.696	13.488

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

BV, net assets; *E*, net income; *r*, cost of capital; φ , abnormal earnings persistence coefficients.

2009; MOF, 2016). Moreover, the low earnings persistence of the shipping industry is considered as a result of high *LEV* (Nam and An, 2017) and high sensitivity of freight rate (Kim, 2011).

Meanwhile, the high earnings persistence of the shipbuilding industry can be attributed to high added value ship orders, economies of scale (KIET, 2012) and intensive support from the government (KMI, 2017). After the global financial crisis, Korea's shipbuilding industry has improved its profitability by placing orders for high value-added ships such as LNG carriers, large container ships, and drill-ships (KIET, 2012). Thus, the high earnings persistence coefficient of the shipbuilding industry shows a high value added that matches the world's No. 1 status.

Table 3 provides the autocorrelation between net income in year *t* and net income in year *t*+1 to examine whether the estimated earnings persistence coefficient used in this study serves as an appropriate classification variable.

The autocorrelation coefficient of shipping industry is 0.196, which is 3.8%

Table 3. The relationship between the future earnings of the shipping industry and the shipbuilding industry

$Earnings_{t+1} = \alpha_0 + \beta_1 Earnings_t + \varepsilon_t$		
Variables	Shipping industry	Shipbuilding industry
	Coefficient (<i>t</i> -value)	Coefficient (<i>t</i> -value)
<i>Constant</i>	-2,041.7 (-0.644)	406.7 (0.334)
β	0.196 (1.879)*	0.793 (10.072)***
<i>Adj R</i> ²	0.038*	0.576***
<i>F</i> -Statistics	3.528	101.442

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Earnings, earnings per share; β , earnings persistence coefficients.

of the explanatory power of earnings after one year. On the other hand, the autocorrelation coefficient of shipbuilding industry is 0.793, and the explanatory power of net profit after one year is 57.6%. This result shows that the estimate of abnormal earnings persistence coefficient shown in Table 2 properly measures the earnings persistence by industry. It also confirms that the relevance to the future earnings of the shipbuilding industry is significantly higher than that of the shipping industry. However, this phenomenon may be caused by the difference between the contracts of shipbuilding industry and shipping industry: the price of new building ships tends to consider the costs of shipbuilding; the freight rate of shipping industry does not overall the costs of ship operation.

In Table 4, this study classifies the full sample into shipping and shipbuilding industry, and then analyze the univariate test whether there are differences between the earnings persistence coefficients of shipping and shipbuilding industry. The mean value of earnings persistence coefficients (φ and β) in shipbuilding industry are 0.592 and 0.793, respectively while those of shipping industry are 0.165 and 0.196, indicating the degree of centrality in shipbuilding industry is significantly higher than that of a non-shipbuilding industry. These significant differences imply that the shipbuilding industry is more profitable than the shipping industry and has high added value.

In the time series model, whether there is a structural change at a specific time and, if so, when is the structural change point is an important issue. The analysis period of this study includes the global financial crisis period (2007–2008). Thus, there is a likelihood that the model parameters have changed as a result of disruptive events. This study conducts Chow test to examines break point of structural change in earnings persistence of shipping and shipbuilding industries. As a result of the Chow-Test, structural changes of earnings persistence occurred in the shipping and shipbuilding industries in 2010 and 2011, respectively show in Table 5. According to KMI (2011), the shipping market has been improved significantly since 2010 due to the recovery of the global economy after the global financial crisis. Thus, structural changes of the shipping industry in 2010 are presumed to the increase of shipping demand following the global economic recovery. In the shipbuilding industry, structural changes occurred in 2011. This seems to be a result that Korean shipbuilders took up half (48.2%) of the world's orders and regained the world's number one position in 2011 (KIET, 2012).

Table 4. Univariate analysis between shipping and shipbuilding industry

		M	Obs	T	df	P-value
φ	Shipping	0.165	95	13.219	171	0.000
	Shipbuilding	0.592	78			
β	Shipping	0.196	95	16.1050	171	0.000
	Shipbuilding	0.793	78			

Table 5. The results of Chow-test of shipping and shipbuilding industries

		F-value	Structure changes year
β	Shipping	8.482***	2010
	Shipbuilding	7.856***	2011

*** $p < 0.01$.

5. Conclusion and Policy Implications

Earnings persistence as the usefulness of accounting information can be used to compare profitability between industries and industries, and also to compare and evaluate net income for different accounting periods in the same industry. This study investigates the earnings persistence in shipping and shipbuilding industry during 16-year periods (2000–2015) using Ohlson model (1995).

The average of the abnormal earnings persistence coefficient (φ) of the shipping industry is 0.165. This result means that the impact of the abnormal earnings of the current year on the abnormal earnings of the next year is 16.5 KRW whereas that of the shipbuilding industry is 0.592, which is higher than that of the shipping industry. In terms of the relevance of future earnings, the average earnings persistence coefficient (β) of the shipping industry is 0.196, but that of the shipbuilding industry is 0.793, confirming that the profitability of the shipbuilding industry is significantly higher than that of the shipping industry. In addition, structural changes of earnings persistence occurred in the shipping and shipbuilding industries in 2010 and 2011, respectively. This result seems to reflect the years of economic recovery of the two industries.

Overall, this study contributes to the literature and practices which provides important evidence for testing the earnings persistence as a useful proxy of earnings quality in Korean shipping and shipbuilding industry. First, research on the quality of earnings as the usefulness of accounting information is very important in academic and practical fields, but a few researches have been done on the shipping and shipbuilding industries. In particular, earnings persistence acts as the most important factor in firm valuation, including investment stock selection, M&A transaction price determination, and Initial Public Offering (IPO) offering price. Therefore, this study provides useful information to support rational investment decision making in shipping and shipbuilding industries.

To the practice, this study provides the implication of government policy maker for Korean shipping and shipbuilding industry. The results of this study show that the earnings persistence of the shipping industry is significantly lower than that of the shipbuilding industry. The recent crisis in Korea's shipping industry is fundamentally different from past crises such as the International Monetary Fund (IMF) foreign exchange crisis. In the past, it was a crisis for individual companies,

but now it is a crisis for the industry itself. The shipping industry is more sensitive to economic fluctuations than other industries and has high management risks, but the economic ripple effect on the forward and backward industries is very large.

Therefore, government policy for shipping industry should be approached in terms of national industrial competitiveness, not as one industry. In the case of the shipbuilding industry, high technology and ship quality are important factors for high earnings creation while in the shipping industry, intangible factors such as cargo service quality, route, and creditworthiness of cargo transportation are important factors for continuous earnings creation. The balance of government policies on the shipping and shipbuilding industries is expected to bring about shared growth between the two main industries in Korea.

This study remains several related issues which requires further studies. First, the risk-free rate of return applied to calculate abnormal earnings uses the industry average risk-free rate of return in the sample period. This assumption is that the distribution of returns for each year has the same cross-section. However, this assumption is unrealistic and the firm's actual cost of capital will be different. The larger the difference between the two capital costs, the greater the likelihood that the error in measuring earnings persistence coefficients will increase, and the results of the study may be affected. Second, earnings persistence may be affected by factors other than abnormal earnings. Moreover, an indicator of shipping business may be important variable to estimate the earning persistence because the business cycle of shipping industry is more vulnerable to the imbalance between demand and supply. Therefore, different results can be obtained by using a different empirical model with some uncontrolled omitted variables.

Disclosure Statement

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Ropax Short-Sea Shipping and Covid-19 Pandemic: Case of Finland

Olli-Pekka Hilmola *

ABSTRACT

Traveling was constantly growing among European Union (EU) countries before Covid-19 pandemic. In many coastal regions, passenger and freight transportation were tied together with roll-on/roll-off passenger (ropax) ferries. However, since the pandemic started, the passenger side of ropax operations has been under numerous new restrictions, bans and requirements. These have changed rather much during the pandemic era in Finland, creating more distortion and profound volume loss. In 2020, governmental support mechanisms were implemented to avoid significant losses. Thus, freight transportation has sustained. In addition, some restructuring and changes of ropax ferry routes have taken place. Now ropax companies concentrate on shorter routes, and volumes are more devoted to certain seaports. However, the situation did not improve in 2021, and subsidies continued, revenues were barely growing, and profitability was limited. Regression models suggest that Covid-19 resulted in a loss of 14.9 mill. passengers and 1.178 bill. EUR as revenue, where unitized freight volumes were unaffected.

Key words : short-sea shipping, ropax, passengers, freight, Finland, Covid-19

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1. Introduction

Before 2020, there did not exist research works in shipping, logistics, economics or business, which would have seen a pandemic as a risk on the horizon concerning passenger transportation at sea. For airlines and hotels, this sort of warning was given, and risk was acknowledged due to earlier Severe Acute Respiratory Syndrome (SARS; 2002–2003) and Swine flu (2009–2010) spreads (Gong et al., 2020; Keogh-Brown and Smith, 2008; Qiu et al., 2018; Sun et al., 2021). Typically, ropax ships and operations risks were related to the ship's navigation and supervision and staff issues or within communication with seaport management and unknown movements of ships at the port area (e.g., Endrina et al., 2018). Collision of the ship with a dock or other ship is always an issue to be taken care of in risk management. However, risk management research did not consider business risks and the rapid deterioration of passenger demand (primary revenue bearing item together with cargo in ropax ship). Within European Union (EU) area, people have been used to own easy access to foreign countries and having no border formalities whatsoever. Same applied worldwide pre-Covid-19 (Coronavirus disease 2019). After Covid-19 took off, people got used to country borders and travel restrictions again, and these even existed inside their own country (counties or city regions under lockdown). The travel industry is very much dependent on freedom of movement and travel safety. Therefore, it has been relatively easy to foresee that the return of, e.g., older people to travel chains will take a long time (even if the current disease spread would diminish suddenly). People, especially risk groups, shall carry a cautious approach for a long time due to applied measures during pandemics (creating long-lasting fear), especially on public transportation modes and travel chains combining these modes (e.g., Christidis et al., 2021).

In earlier research, ropax ships have been identified as highly emitting transportation units (Christodoulou et al., 2021; Durán-Grados et al., 2020; Hilmola et al., 2015). However, these typically offer good connectivity for both passengers and cargo. As one solution earlier, research has found to use a slow steaming strategy at ships (using slower speed to gain significantly lower oil usage). However, it is still not widely applied (Raza et al., 2019). Also, traffic jams, roadside pollution, and road infrastructure need declines if ropax ships are used and favoured in political decisions (Morales-Fusco et al., 2018). The aftermath of demanding environmental regulation in the Baltic and North Seas (very low sulphur content allowed on ships from 2015 onwards) resulted in many North European countries' increasing use of ropax and roll-on-roll-off (ro-ro) ships together with trucks and semi-trailers (Hilmola, 2019). In one way, ro-ro and ropax lost within longer distance connections; however, shorter distances experienced significant growth (Hilmola, 2019). Christodoulou et al. (2021) concluded similarly concerning future emission reduction plans that ropax/ro-ro ships emit a

lot of CO₂ and will face significant competitive pressure from hinterland transports if sea transportation is required to pay for its emissions in the EU area. Therefore, it is somewhat logical to assume that possible future CO₂ payments shall translate to higher transportation prices for customers. This has already happened with the changes driven by the sulphur regulation and the increasing diesel price (Raza et al., 2019). In many shipping companies, increased operating expenses were just passed to customers in a form of surcharges of incurred fuel costs (Bunker Adjustment Factor).

This research is structured as follows: Literature review concerning short-sea shipping drivers and enablers is provided in Section 2. Research methodology and environment follows in Section 3. As in Section 4 is analyzed the overall situation of ropax operators serving the Finnish market – it consists of an aggregate-level analysis of passenger amounts, freight volumes, and financial performance. In Section 5 is presented unitized freight flows to/from Finland with the main ropax partner countries of Estonia and Sweden. A similar analysis follows concerning passenger flows in Section 6. Research is concluded and discussed in Section 7, where additional future research avenues are also being proposed.

2. Short-Sea Shipping of Roro and Ropax – Drivers and Enablers

Short-sea shipping using ro-ro or ropax vessels has been examined mostly from the freight perspective, and if passengers are concerned, research typically leans on safety issues of maritime transport (e.g., Zeng et al., 2017). However, it should be emphasized that short-sea shipping could include all the other cargo classes too, and has been most popular among EU countries (consists of one-third of intra-EU freight movements; van den Bos and Wiegman, 2018). Based on van den Bos and Wiegman (2018) research, usage of ro-ro shipping in the EU area is driven by the higher amount of short-sea shipping seaports in a particular country, its road network length, and country's smaller land area. In other words, it is mostly popular among smaller countries with good logistics infrastructure. As said earlier (Durán-Grados et al., 2020; Hilmola et al., 2015), emissions of ro-ro and ropax ships have been on the societal agenda for years, and in most recent studies, even electricity and hydrogen are being proposed as solutions for significant emission reductions (e.g., Tapaninen and Palu, 2022; Vidas et al., 2021).

It is known that ro-ro and ropax ships are mostly competitive because of speed and lead time reduction and are not necessarily the lowest cost compared to lift on-lift off ships (like container ships). Customers favor ro-ro and ropax within freight transportation as their supply chains become more compressed, where chains could be managed with lower inventory levels and they are more reactive

and flexible on market changes (Zheng et al., 2021). It was illustrated in the study between South Korea and Japan that the lead time advantage of ro-ro based maritime transportation from departing seaport gate to arrival seaport gate is approx. 65%–70% lower than container ships (Zheng et al., 2021). This lead time saving arises mostly from port handling as in ro-ro ships it is very efficient and has short duration (Zheng et al., 2021). In addition to this, time spent at sea also has shorter duration, but the difference is not so dramatic as what it is at seaport operations. However, it should be emphasized that ro-ro and ropax freight transportation is never a low cost, and freight users of it typically have more valuable cargo to be transported (Zheng et al., 2021).

Even if ro-ro and ropax shipping use could be connected on the technical side, especially within innovations of loading-unloading and higher speed of sea vessels, it is only the second part of the major competitiveness equation. For example, in Asia, ro-ro and ropax usage is much lower than in Europe (also, research works are mostly done in the latter, e.g., Raza et al., 2020). The empirical study of Arof (2018) illustrates that experts consider the most critical enabler of ro-ro shipping in South-East Asia to be the regulatory changes in the countries and regions involved. Ro-ro and ropax shipping, to be effective and efficient, require swift border formalities with a low amount of administration and appropriate safety and security processes (the latter one also in surrounding waters). In addition, shipping agreements and restrictions need to be eased. Many experts also saw governmental financial assistance as an essential part of implementation's early phases. Another study outside Europe area conducted by García et al. (2021) reported that ro-ro shipping has been growing even in the Caribbean area, especially during the pandemic. It could be said that within the EU area, most of these regulatory challenges have already been resolved with political integration, and different programs are economically favouring intermodal transportation (e.g., Raza et al., 2020), and in some research works, it is currently seen as a vital or most important issue to increase the speed of vessels at sea. However, it should be emphasized that increasing speed is just one of the last phases of increasing competitiveness (Renna et al., 2021).

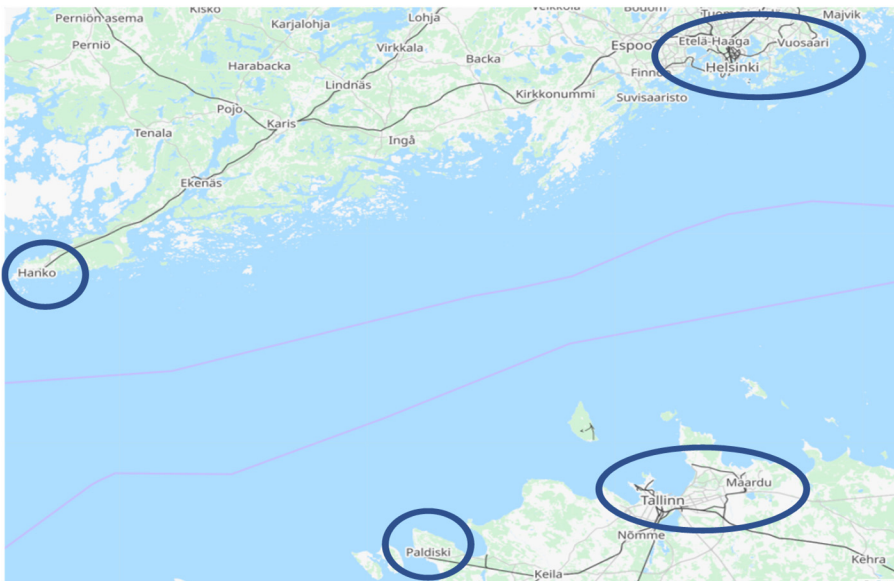
3. Research Methodology and Environment

Through longitudinal second-hand statistics and financial reports of companies, this research analyses the situation of ropax companies serving Finland. Data arise from companies (annual reports), national statistics and branch-specific databases of Finland and then from EU (Eurostat) statistics. In many used datasets, observation periods ended in 2020, but in aggregate indicators, availability is for both pandemic years (2020–2021), and research uses regression models and analysis to illustrate Covid-19 effects. Regression analysis was chosen because it is one of the few applicable statistics analysis approaches in the longitudinal data

series and in situations where there are numerous parameters (regressors) potentially explaining the volume or revenue development. The following are used as regressors for two variables, namely time (year) and Covid-19 pandemic era (binary, years 2020–2021). Earlier research in the freight sector has used regression analysis extensively. For example, Hilmola (2014) used it to detect factors explaining unitized/general cargo sea freight growth between Finland and Estonia, whereas van den Bos and Wiegman (2018) used numerous potential parameters to find reasons for short sea shipping popularity in Europe. Tao and Zhu (2020) built regression models to explain the factors behind the value of time in freight transport. What is different in this research in the applying of regression analysis, is to use its outcomes to forecast passenger recovery, and year when pre-pandemic level of passenger volumes could be reached.

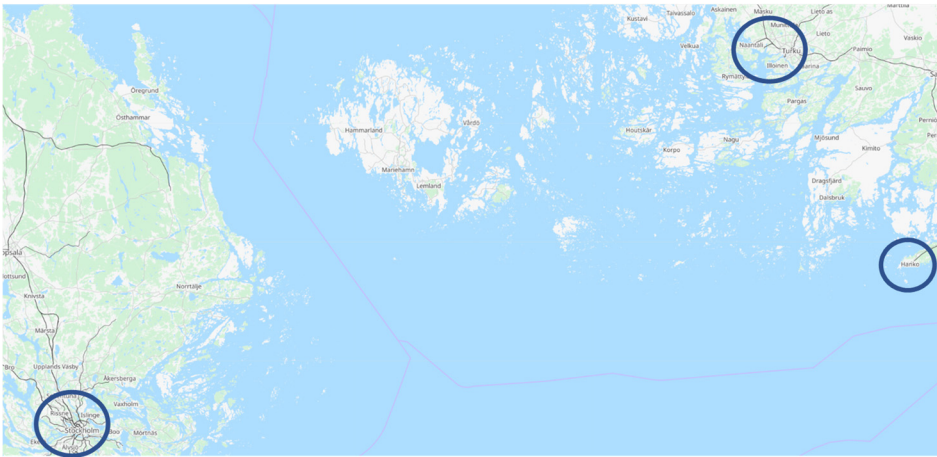
Finland is located in the North-East of Europe and is merely an island on the European map as hinterland connections exist only to Russia and within very north to Sweden and Norway. Other countries and meaningful European connections are always behind the Baltic Sea. So, short-sea shipping plays a vital role in freight flows and passenger movements together with air transportation mode. As the population in Finland is relatively small (5.5 mill.), short-sea shipping is often a combination of freight and passengers – both are needed to make operations profitable. However, combining these two makes it possible to have numerous daily connections to nearby countries, like Estonia (Figure 1) and

Figure 1. Map concerning two Finnish seaports of this study (Hanko and Helsinki) as well as two Estonian seaports (Paldiski and Tallinn).



Source (background map): OpenStreetMap contributors (2022).

Figure 2. Map concerning three Finnish seaports of this study (Hanko, Turku, and Naantali) as well as one Swedish seaports (Stockholm).



Source (background map): OpenStreetMap contributors (2022).

Sweden (Figure 2). This all worked well until the coronavirus pandemic hit Northern Europe in early March 2020. After that, passenger volumes have been in turmoil, and sudden declines have followed political restrictions of lockdowns and/or very demanding restrictions to travel. Due to this, financial support has been provided for ferry operators from the local governments of Finland, Estonia and Sweden. However, as ferry operations are having such a large scale, it is evident that government subsidies are not enough to cover all losses incurred. Therefore, this research aims to answer the following research question: How did the coronavirus pandemic affect ropax companies and Finland's seaports? This research aims to examine how robust ropax operations are in the pandemic environment and provide perspectives for earlier research in the field as they, e.g., saw risks from a minimal angle, and the importance of passenger flows has not been adequately understood.

4. Overall Situation and Development of Ropax Operations

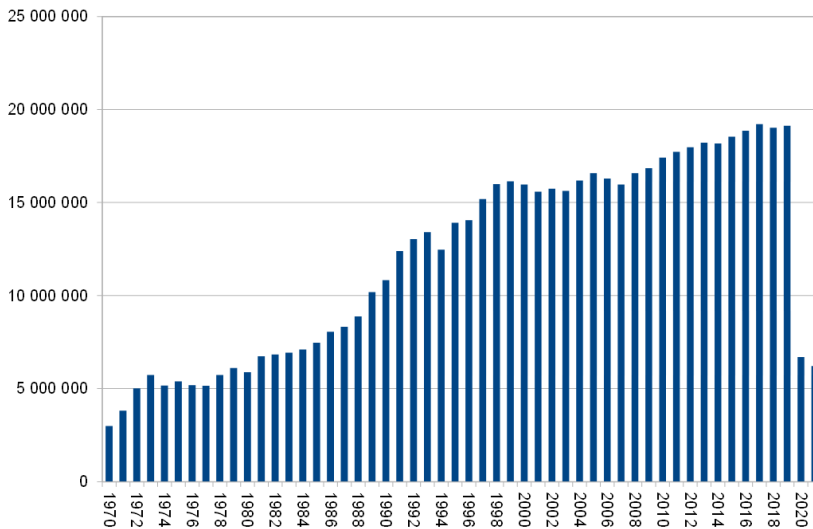
The long-term popularity of ropax ferries to/from Finland within passenger transportation is apparent as examining Figure 3. During five decades (1970–2019), passenger transportation volumes increased 539.4%. In 2018, the Helsinki seaport was the busiest passenger transportation seaport in the whole EU area, as Tallinn (Estonia) reached third place and Stockholm (Sweden) seventh (European

Commission, 2020). In the first two decades, the volume growth of Finland was mostly driven by Swedish connections. Many people from Finland were engaged in the job market of the western neighbour (Sweden was instead receiving rather diverse immigration from different European countries early on; Rauhut, 2010). Also, trade was rampant, which resulted in a higher need for business travel. Together with these factors, tourism was a driver and the desire of people, groups and families, and this was often completed by taking sea cruises. As a result, passenger volumes were present from Finland and Sweden.

However, without the collapse of the Soviet empire and the regained independence of the Baltic States, notably Estonia, the volume growth of Figure 3 would not have continued for three more decades. In the late 1980s and early 1990's, it was popular for Finnish people to visit Estonia for touristic reasons. After Estonian independence was regained in 1991, many manufacturing businesses moved to this new low-cost country. In addition, Estonians were eager to visit Finland and started to take part in the job market. As shown in Figure 3, the growth of 1990's was much steeper than before – as from 1970 to 1989, passenger transportation volumes grew by 7.2 mill. passengers, from 1989 to 1999 they grew by nearly 6 mill. passengers higher. So, the growth rate measured against time nearly doubled. After this steep increase, growth matured for nearly a decade but started again after 2008–2009. After that, growth was much more moderate but still present. The reasons were the same as before, but now people and businesses started to understand that you could conveniently make same-day or one-to-two-day visits. This increased, e.g., short-term job market and tourism visits a lot (worker travel intensity is one of the highest between Estonia and Finland, especially among Estonians participating in the Finnish job market; Anniste et al., 2017).

It could be said that everything changed in ropax passenger transportation in Finland due Covid-19 pandemic. The first two months of 2020 were developing like 2019, but in March 2020, a steep volume decline suddenly stepped in. This was further accelerated by the governmental decision to allow only necessary travel, nothing else. For summer 2020, regulations were relaxed, and people returned to ferries. However, in the autumn time, infections accelerated again higher, travel volume started its dive, and regulations only increased further (only necessary travel again allowed). During the winter of 2020–2021, regulation changed again, and people travelling were much smaller occupation groups than before. For summer 2021, regulations were relaxed, but for borders started to appear Covid-19 test requirements (actually two tests, if you entered Finland, before border-crossing or at border-crossing point, and some days after arrival), however, easing requirements for fully vaccinated persons. The result of these policies and political changes was that passenger transportation amounts declined in 2020 by 65% from the previous year, and in 2021 volumes continued to decline further (–7.14% as an annual change). There is no comparison point in Figure 3 to this sort of two-year decline – the highest proportional decline is from 1974

Figure 3. Passenger transportation volumes in Finnish seaports during 1970–2021.



Source (data): Statistics Finland (2022).

(−9.9%), followed by a decline in 1994 (−7.1%). To illustrate the profound change of Covid-19, a regression model from overall passenger volumes was built. There were two explaining factors for passenger volume of Finland – time (year) and Covid-19 (in years 2020 and 2021 having a value of one, and otherwise zero). A regression model was able to forecast 95.6% of annual passenger volume (Appendix 1), where both effects of time and Covid-19 were statistically significant (below 0.001 level). Annually, starting from 1970, passenger volumes have grown by 0.35 mill. passengers per year. However, Covid-19 had a destructive effect, where 14.9 mill. passengers were lost in both years 2020 and 2021. The effect of Covid-19 is 42.4 times higher than the annual growth of passengers – this gives perspective for forthcoming years in passenger transportation. Without the sudden end of the pandemic and/or removing all travel restrictions, it is very difficult (or nearly impossible) to reach back to pre-pandemic levels in passenger volumes.

Table 1 illustrates three different scenarios of waning Covid-19 effects (using coefficients of regression model) – in the most optimistic scenario passenger volumes would be back to 2019 levels in 2024, but in pessimistic situation it could take until 2028. All of these scenarios assume that Covid-19 effects will gradually diminish and in 2022 and onwards no full effect year will not any longer come.

In absolute travel number terms, volumes of 2020 and 2021 were at the level of 1980–1981. Swedish ropax connections experienced a higher decline in 2020 as passenger volume declined by 72.9%, while in Estonian routes, the decline was 53.8%. In 2021, Swedish connections experienced some recovery as they grew from 2020 by 23.74%, whereas the Estonian route lost 22.3%. If the year 2021

Table 1. Passenger transportation volumes in three different scenarios tackling Covid-19 effects.

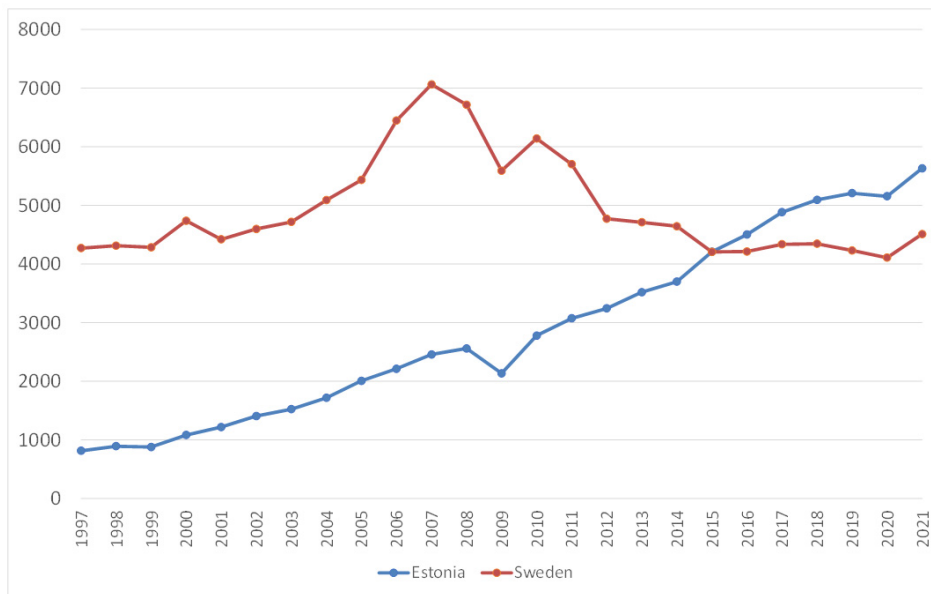
Year	Pessimistic	Normal	Optimistic
2019 (act)	19,135,108	19,135,108	19,135,108
2020 (act)	6,689,327	6,689,327	6,689,327
2021 (act)	6,211,512	6,211,512	6,211,512
2022	8,462,894	9,949,275	11,435,656
2023	10,300,004	14,015,956	16,245,527
2024	12,137,114	18,082,637	19,569,018
2025	13,974,223	22,149,318	22,892,509
2026	15,811,333	23,243,238	23,243,238
2027	17,648,443	23,593,967	23,593,967
2028	19,485,553	23,944,696	23,944,696
2029	21,322,663	24,295,425	24,295,425
2030	23,159,773	24,646,154	24,646,154

Pessimistic: 90% Covid-19 effect in 2022, and declining by 10% points every year, being 10% Covid-19 effect in 2030; normal: 80% Covid-19 effect in 2022, and declining 25% points in three following years, and thereafter being 0%; optimistic: 70% Covid-19 effect in 2022, and declining 30% percentage points in 2023, and 20% in 2024, and thereafter being 0%). Shaded gray area in table for years, when pre-pandemic passenger volume is reached.

volume is compared in Swedish and Estonian routes, it could be said that roughly two-thirds of passengers have been lost due to the pandemic era. In relative terms hardest hit was the Helsinki-Stockholm route – in 2020, Helsinki seaport passenger transportation volumes with Sweden declined by 83.5%. This was a partially business-based decision of two ferry companies to cancel this connection. The situation and passenger volume on this route were the same in 2021, showing only modest 7.84% growth from 2020. Route to Sweden from Helsinki is much longer than, e.g., Turku or Naantali, and there must have been business rationality behind this. The lowest decline in passenger amounts in 2020 was experienced in Naantali (–24.9%), and it also recovered in 2021 (+15.3% from the previous year). However, it should be stressed that this connection to Sweden could be mostly classified as ro-ro ship and serving that of freight (trucks and drivers).

In ropax ships, another critical stream of revenue is unitized freight (i.e., semi-trailer trucks onboard). This is an important customer group as trade and logistics flows to nearby countries are often the most intensive. In the situation of Finland, this is the case too. As Figure 4 illustrates, freight volumes have been with Sweden from four to seven million tons from 1997 to 2021. However, as Swedish trade is more mature, it is hardly growing. For example, the total trade of Sweden and Finland in euros was nearly the same in 2020 as it was in 2008. However, global economic recovery in 2021 resulted in total trade growth of 20.3% from 2008. Particularly problematic has been Finnish exports, which are still at the level

Figure 4. Unitized freight transportation volumes in Finnish seaports during 1997–2021 to/from Estonia and Sweden (unit: 1,000 tons).



Source (data): Eurostat (2021a), Traficom (2021; 2022).

of 2005; understandably, freight flows will then show no growth. In addition, Sweden no longer offers the best hinterland opportunity for transit to other European countries due to environmental restrictions and payments (road use charges and higher cost fuel). In Europe, manufacturing activity has increasingly shifted to the east. As a result, unitized freight volumes declined from the previous year in 2019 (–2.6%) and 2020 (–2.9%). However, the year 2021 witnessed abnormal growth of 9.8% from 2020. It should be emphasized that freight volumes were in coronavirus years 2020–2021 at the same level (2020 a little bit lower and 2021 slightly higher) as they were in the first year of the observation period, 1997. As there is no long-term trend in Swedish freight traffic, it is understandable that the regression model using the time (years) and Covid-19 era as regressors did not gain any statistical significance (Appendix 2).

However, the Estonian route is opposed to this, where freight volumes have constantly been growing only with minor annual corrections (1999: –1.6% and 2009: –16.6%). The year 2020 of the corona crisis also led to a slight decline compared to 2019 (2020: –1.0%). However, this was rapidly recovered in 2021 by annual growth of 9.2% (repeating exactly the same pattern with earlier corrections, which were recovered shortly in the following year). Although Estonia is a much smaller country in population and economic terms than Sweden (e.g., Hilmola, 2019), it is now bigger in short-sea shipping unitized freight with Finland. There

are reasons for this (numerous factors contributing to long-term growth: Hilmola, 2014). One of them is the opportunity for manufacturing, trade, and other businesses (like the service industry, laundry services etc.) to use Estonia or the other Baltic States as a part of their supply chains to have much lower costs and still have a good level of quality and service. Also, the hinterland position of Estonia is beneficial as one may reach large Central European markets (Poland, Czech Republic, Slovakia, and Germany) by truck or train, in addition to emerging eastern markets (Belarus and Ukraine). The sea journey between Estonia and Finland is relatively short (approx. 80 km), and it takes typically 2–3 hours for ropax ships to sail the route in one direction. This has been an important competitive advantage in recent decades as sea transportation has become higher priced due to more demanding environmental standards (such as sulphur regulation, resulting in higher fuel costs; Hilmola, 2019). In the regression model, where volume development was explained with time (year) and the Covid-19 era, it was found that time was statistically significant (below 0.001 level) and was alone explaining the volume progress with a high precision rate (R^2 is 97.4%). As Appendix 3 shows, unitized freight volume increases by 206.1 thousand tons every year (time-based co-efficient has slightly increased as in Hilmola's (2014) research it was 175.2 thousand tons per annum). Covid-19 effects were not statistically significant in the model.

During pandemic times, the financial performance of three ropax companies serving the Finnish market was dramatically worsened. In 2020, revenues declined to roughly half of 2019 (–55.4%; Figure 5). Recovery in 2021 was somewhat limited, where revenues improved by 14.2% compared to 2020. The regression model was built to reveal reasons for revenue change. Time (year) is statistically significant and positive in the model (annually revenues increase 52.2 mill. EUR), whereas Covid-19 period (binary, being one in 2020–2021, while in other years zero) in turn was big negative impact event with even higher statistical significance (Appendix 4). Based on the model, Covid-19 reduced revenue annually 1.178 bill. EUR. These two regressors explain 72.4% of revenue development over the years. Again the Covid-19 effect is massive compared to time-based annual increases – being 22.6 times higher in magnitude. Getting rid of Covid-19 effects is a key to reaching pre-pandemic revenue levels.

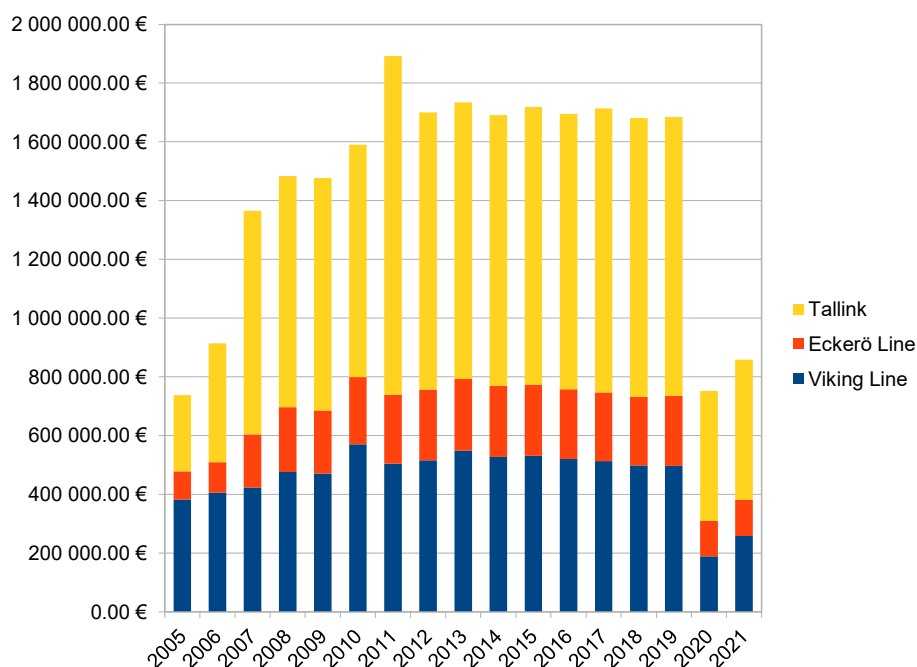
Local governments in Finland, Estonia, and Sweden provided support packages for these companies. However, packages were just to provide the ability to carry operations on, and this in operative cash-flow terms. Shipping is an asset-specific business, and annual depreciation of assets (shipping fleet) has a significant fixed impact on total costs and continuous maintenance of these assets. Therefore, were deficits rather significant in 2020. In total, these three companies made 184.4 mill. EUR of loss in 2020, which could be compared to 2019, when profits were 61.3 mill. EUR (2019 was a somewhat “typical” year in profit terms). As all three ropax companies are reporting publicly their financial performance (all have a public shareholder base), the big picture in 2021 has not changed

significantly better as total losses amounted 62.8 mill. EUR.

Regarding financial deficits, the situation has varied among the three companies. The largest operator, Tallink, which operates extensively with three ropax and one roro ship(s) at the Helsinki-Tallinn route and having two ropax ships on the Turku-Stockholm route as well as two ropax ships on the Helsinki-Stockholm route. In addition, other ropax routes have been available and operating, like Tallinn-Stockholm and Riga-Stockholm. Tallink has reported that its losses were approx. half in 2021 as compared to 2020. In Eckerö Line, which operates one ropax and roro ship on Helsinki-Tallinn route, and some freight and passenger transportation from Åland to Finland and Sweden and other countries), deficits are at a similar level in 2021 as what they were in 2020 (with slight improvement). Viking Line, operates one ropax ship throughout the year at Helsinki-Tallinn route, and two in Turku-Stockholm as well as one in Helsinki-Stockholm route, also other shipping services between Finland and Sweden, is the only ropax operator showing profits in 2021 – this was primarily due to assets sales in accounting year with profits (as compared to balance sheet value; sold ropax vessel and passenger terminal). However, all three companies have continued to receive governmental subsidies (due to pandemic) in 2021, and losses are higher than the overall sum of 62.8 mill. EUR.

It is important to analyze further why revenues and profits declined so significantly in 2020 (and recovery has been weak in 2021). The largest actor of ropax companies, called Tallink, has the most developed reporting structure among these three companies (e.g., Tallink, 2019). In 2019, they showed that 56.5% of revenue was gained from product and restaurant sales (both provided in ships and within some hinterland locations). The second-largest revenue stream was ticket sales (passenger), which had a share of 25.4%. In addition to maritime services, Tallink also owns some hotels, and their revenue share in 2019 was 1.7%. If all these three are summed together, it could be concluded that 83.6% of revenues were significantly dependent on passenger transportation, services and tourism. Therefore, it is understandable that freight transportation of ships cannot cover or save these companies alone – freight rates would need to increase with very high multiples that this would be a reality. Without removing restrictions on travel and gaining the willingness of people to use these services as before, shipping companies have difficult times ahead, and restructuring operations is the most probable route to proceed further. So, the lowest profitability routes are evaluated, possibly resulting in vessel sales (as the second-hand market is so lucrative due to globally high inflation and lower restrictions in other countries). However, it should be highlighted that not all shipping firms are in trouble – those concentrating on freight have done rather well in the crisis year 2020 and exceptionally well in 2021. For example, a well-known roro shipping company, called Finnlines was showing decent profits even in 2020, and it primarily serves Finland and Northern Europe (Finnlines, 2021).

Figure 5. Revenue development of three short-sea shipping (ropax) operators serving Finland.



Source (data): Annual reports.

5. Freight Flow Changes

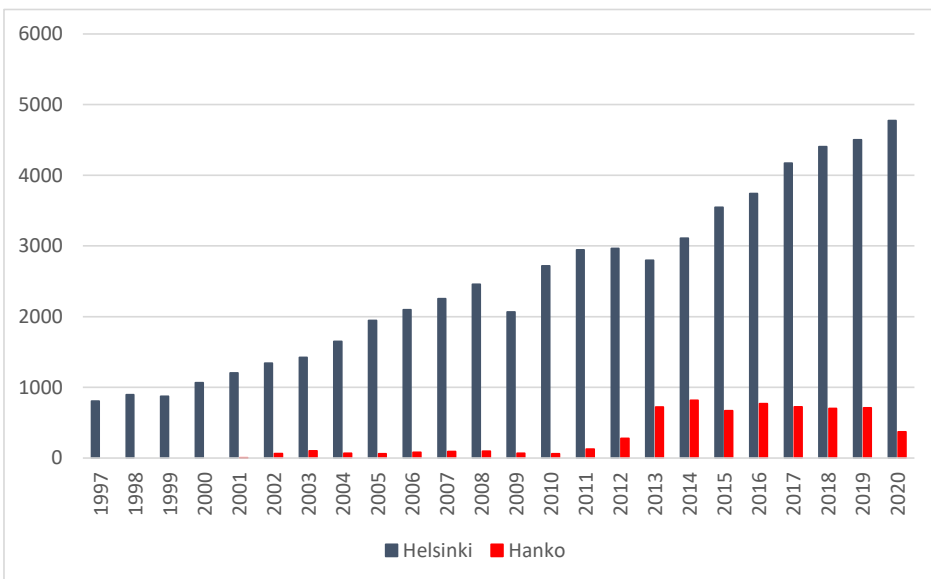
Earlier it was concluded that unitized freight volumes between Finland and Estonia and Finland and Sweden were declining during the corona crisis year 2020. This is an aggregate situation, but development varied between different seaports a lot. It should be reminded that unitized cargo in this analysis is primarily trucks with a semi-trailer. In some situations, there is only a semi-trailer (that is rolled on and off with tractors). Semi-trailers could also be carrying containers. However, unitized cargo seldom consists of solely containers (without trucks), so most cargo is transferred on routes with ropax or ro-ro ships.

At the aggregate level, it was said that Estonian unitized cargo declined a little bit in 2020. In Finland, Estonian unitized cargo has been completed by two seaports, namely Helsinki and Hanko (both in the south and not that far away). All Estonian year-round operating ropax ships call Helsinki (in summer months, there have been some very marginal connections to other ports). It offers numerous departures per day with high frequency to the old city of Tallinn. Two other ships in the Helsinki-Tallinn route are merely ro-ro ships, and they both use Tallinn's

cargo port, Muuga. Hanko has been serving only roro ships, and this is in route of Hanko-Paldiski (westernmost location of Estonia). The year 2020 changed the situation between Helsinki and Hanko so that Helsinki grew in freight volumes as Hanko declined (Figure 6). It was actually so that the Estonian connection of Hanko was cancelled in the final months of 2020 as there was not enough cargo (freight operator shifted roro ship to another route, serving Estonia-Sweden).

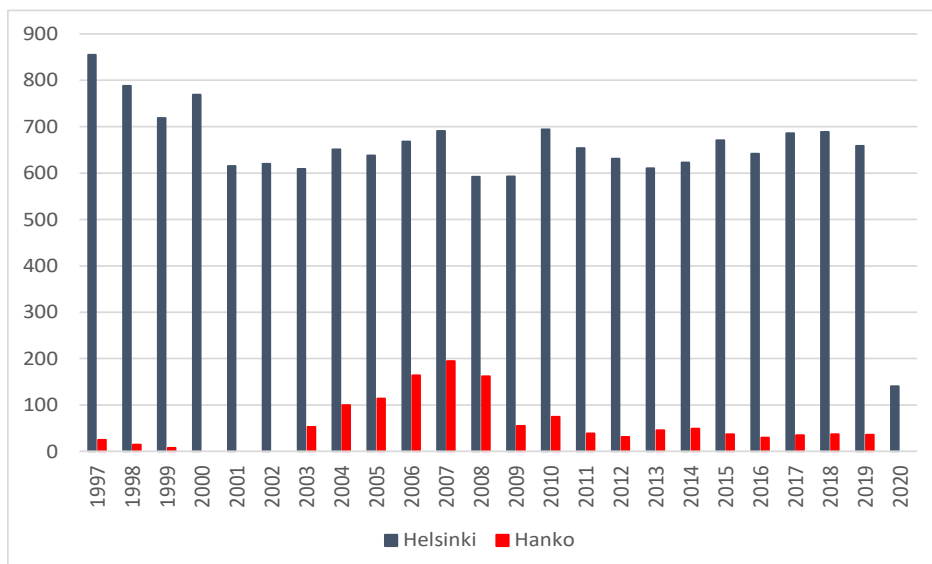
Swedish unitized freight situation of seaports was more diverse before the coronavirus crisis. Freight flows were shared among three seaports, namely Helsinki, Turku, and Naantali. In addition, some roro ships operated from Hanko and one ropax ship from Vaasa to Sweden. However, in 2020 rather drastic changes took place. First, freight volumes to and from Hanko ceased to exist. With this, ropax connections (in total, four ships and two different companies) from Helsinki to Stockholm were taken off due to governmental restrictions and the lack of travel demand. However, it was a business-based decision in the end. Figure 7 illustrates the situation further – the decline in Helsinki freight volume was 78.7%. However, the situation in the Swedish direction is similar to Estonia – the largest ones benefitted from the crisis and absorbed the volumes. Two westernmost seaports, Turku and Naantali, were growing in 2020, as Figure 8 shows. Turku benefitted most in both relative and absolute terms. It should be highlighted that from

Figure 6. Unitized cargo transportation to/from Estonia from the seaports of Helsinki and Hanko (unit: 1,000 tons).



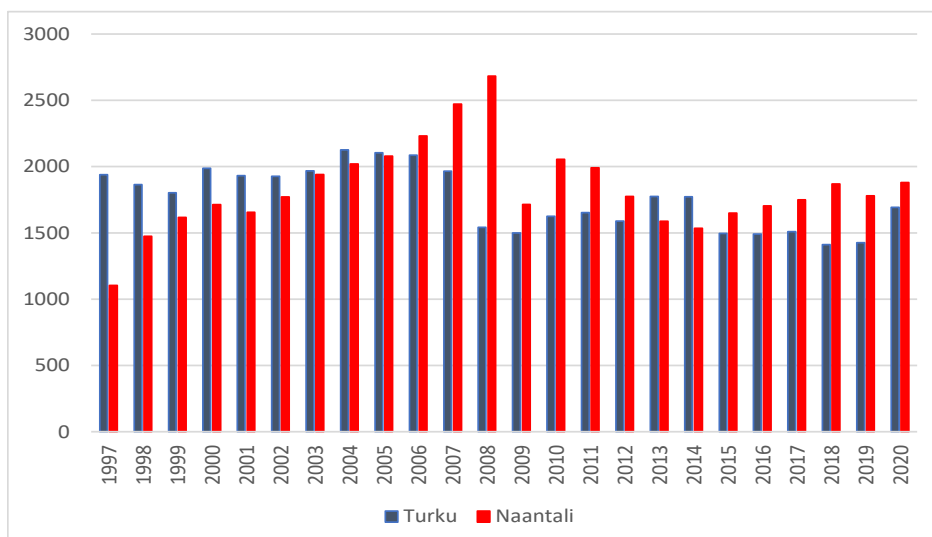
Source (data): Eurostat (2021a), Traficom (2021).

Figure 7. Unitized cargo transportation to/from Sweden from seaports of Helsinki and Hanko (unit: 1,000 tons).



Source (data): Eurostat (2021a), Traficom (2021).

Figure 8. Unitized cargo transportation to/from Sweden from seaports of Turku and Naantali (unit: 1,000 tons).



Source (data): Eurostat (2021a), Traficom (2021).

Naantali, there are no ropax connections to Sweden, but it is served by two roro ships (two).

In 2021, the situation did not change that much. Hanko is still without a unitized regular cargo connection to Estonia, and ropax ships operating between Helsinki and Stockholm were for a long time out of route (ships were brought back to route in July/August of 2021). In addition, one ship (out of four) from the Helsinki-Stockholm route was sold abroad. So, the situation remains more or less the same as in 2020, where the most prominent volume routes grew in dominance over smaller ones.

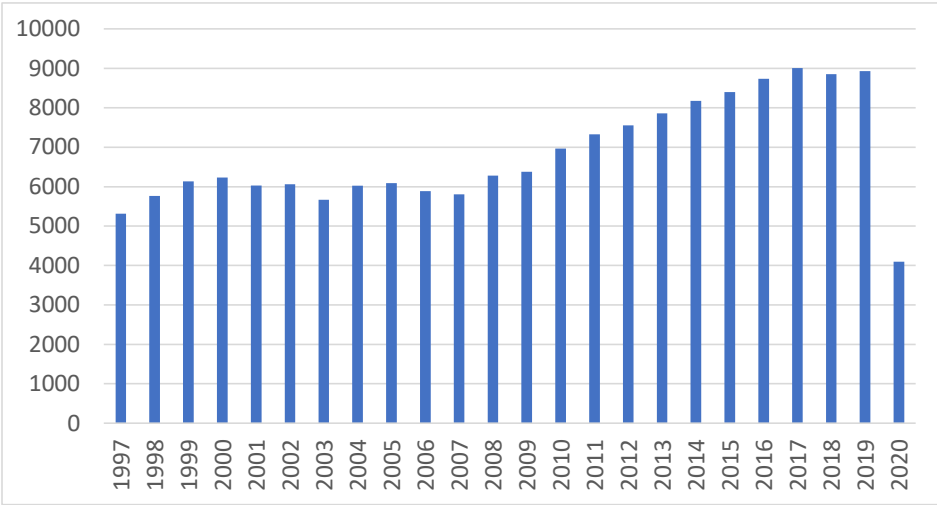
6. Passenger Flow Changes

Earlier sections concluded on an aggregate level and within seaports on how passenger transportation developed in 2020. Loss of volume was substantial (65% decline in passenger handling of entire Finland). However, an additional angle to passenger transportation volume development from a long-term perspective could be gained from other statistics, which only examine passenger volumes crossing country borders (Eurostat, 2021b). This statistical database is the only source having long-term data available from particular seaports and passenger flow directions. However, it should be highlighted here that many passengers in ropax ships are just taking cruises and do not necessarily enter other countries. This was a prevalent short-distance touristic form in the pre-pandemic era (for decades). Examining only passenger flows, crossing borders could provide long-term visibility as touristic flows for cruises will take longer to come back after the pandemic – it could be assumed that the need for travelling is more real for people crossing borders.

During the pandemic year 2020, passenger transportation border crossings dropped significantly. However, countries and seaports do differ. The best performing was Estonian direction (Figure 9), where ropax ferries out of Helsinki lost 53.7% from the volume of 2019. This volume is also the lowest in the entire observation period starting from 1997 (actually, the year 2020 is 22.8% lower than 1997). For Finnish Estonian connections, Helsinki is the sole seaport offering connectivity (there exist some minimal volumes from other seaports, but that has been for summer travel and developed packages).

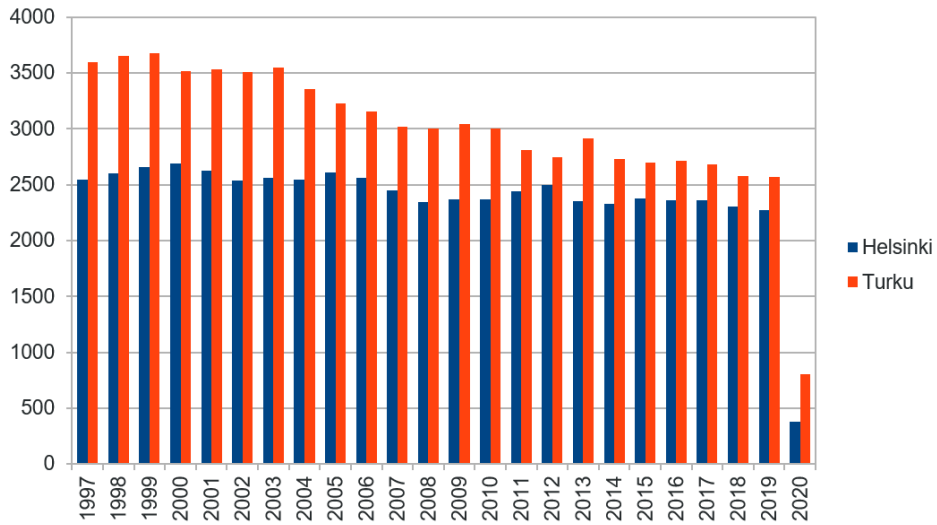
For Swedish ropax connections, border-crossings have developed much less favourably (Figure 10). From Helsinki, passenger volumes declined 83.5% (partly could be explained by ropax operators' shut down Helsinki-Stockholm connection during 2020). From Turku, the decline was lower but still substantial, 68.7%. There are other seaports of Finland (Naantali and Vaasa) offering also connectivity to Sweden, but passenger volumes are much lower. For example, in these statistics, Naantali was performing best as it lost only 24.4% in 2020 (as

Figure 9. Passenger transportation to/from Estonia from the seaport of Helsinki (unit: 1,000 passengers, excluding cruise passengers).



Source (data): Eurostat (2021b).

Figure 10. Passenger transportation to/from Sweden from seaports of Helsinki and Turku (unit: 1,000 passengers, excluding cruise passengers).



Source (data): Eurostat (2021b).

mentioned earlier, it is roro connection). From Vaasa, there is also ropax connection to Sweden, and it experienced in 2020 decline of 72.5%.

From a long-term perspective, if examining both Figures 9 and 10, it could be concluded that passenger transportation volumes were already experiencing levelled off or declining development before 2020. For example, Estonian connection could not show growth after 2017. In addition, Swedish ropax connections from Helsinki and Turku are clearly on a long-term declining path. Due to this reason, it is not easy to forecast future volumes. If coronavirus eases and diminishes from the earth, then Estonian ropax connections at best are in the volume levels of 2017–2019. This could take time as the psychological effect of the pandemic must be well placed in the memory of older people (who might be frightened to take travel services as before). In Swedish connections, passengers' volumes will probably seek to catch declining trajectories in the long term. So, in the post-pandemic world, volumes are probably lower than in 2019.

7. Conclusion

For five decades, ropax ships serving Finland were enjoying the long-term growth of passenger transportation, and there seemed not to be any dangers on the horizon. There were some periods of moderate or levelled off demand, but passengers' volumes never declined by more than 10% from the previous year. After these earlier declines, passenger volumes always recovered in the following year. However, the years 2020–2021 and the coronavirus pandemic showed a clear difference. In 2020, passenger volumes declined by 65% in all Finnish seaports. In 2021, the situation has remained on a declining path, which differs from previous years of challenging demand. The built regression model revealed that Covid-19 reduced passenger volumes by 14.9 mill. passengers per year. Another regression model further illustrated change as revenues were reduced annually by 1.178 bill. EUR. It could be said that ropax operators serving Finland are currently experiencing the hardest time in record, and for risk management of the future, pandemics need to be taken better into account, e.g., concerning investments and pricing (compared to pre-pandemic risk models, e.g., Endrina et al., 2018; Zeng et al., 2017).

The situation seems not to be just a contemporary softening of demand. However, it seems that this depression will last for a more extended period. This is in line with Christidis et al. (2021) simulation research, where pre-pandemic demand of EU-27 countries in airline travel will be reached in 2030, and for public transportation modes, like rail and bus, it will take even longer. Of course, it depends significantly on disease situation as well as political decisions (latter as the most important item of roro and ropax shipping growth within Arof (2018) study), how forthcoming years will develop at ropax shipping (based on studies

spreading of Covid-19 as taking airline travel is very low). However, passenger volumes distribute the virus to destinations later-on (Sun et al., 2021). If the virus disappears in the summer of 2022, northern countries may get back to normal, and we may see some growth in 2022 (as Table 1 illustrated through three different scenarios). However, if politicians see that closest neighbours and borders are the worst places to spread the virus, it is questionable to see growth in 2022, and recovery will occur later, in 2023 or 2024. Anyway, three to five years of significant volume loss in passenger volumes will need time to recover. Therefore, the years 2024–2028 could be estimated with current knowledge (Table 1) as a period when passenger demand is at normal pre-coronavirus level (in some situations, pre-virus volume levels might not ever be reached, as concluded in earlier sections). If virus waves will be around for a more extended period (than 2022–2023), then it is understandable that use 2030 as the earliest typical demand year is justified.

What has been positive and sustaining during the Covid-19 crisis for ropax shipping companies has been the demand for the freight segment. Regression models did not find any relationship between freight volumes and Covid-19 era. The year 2020 was a challenging year in worldwide demand terms for unitized cargo. However, ropax operators serving Finland experienced rather good demand even then (having only a minor decline). Freight volumes have developed in a rather good manner in 2021. This is also reported in other regions in the earlier study by García et al. (2021). Also, prices globally for sea transportation have been under pressure, and huge increases in freight rates have been seen in containers (but other cargo segments have followed this). This provides an opportunity for ropax operators. If freight rates continue to increase, even in more local sea transportation, this offers a path to shrink losses and increase revenues. However, it is difficult for these companies to handle more freight as ropax ships are built to serve both trucks and private cars/lorries. If the latter ones do not have that much demand, it is not easy to load more trucks on higher decks. It is to be seen whether ropax operators will enlarge their presence in freight services as they did earlier with passenger transportation (offering services at ships, selling products, providing hotel services, and taxi transportation). For example, enlarging to trucking or warehousing could be one option. In the end, it should also be noted that ropax freight is already serving time-sensitive and time-based supply chains, and it is typically higher priced than containers (Zheng et al., 2021). Therefore, it is not that apparent that prices could increase promptly as starting ground is already higher. In addition, emission reduction schemes and possible payments in the forthcoming years decelerate the competitiveness of ropax vessels in the freight segment (Christodoulou et al., 2021).

As further research concerning ropax operations in Finland, it would be interesting to examine how to ship type shall change in the future. The earlier recipe for success was building glorious ships, which served passengers and consumptions well, and where freight was served alongside it. Currently, two of

the three analyzed companies hold one ro-ro ship each, serving the Estonian route. These have been relatively successful in the current environment and could be showing a path forward in the construction of future ships. So, it means fewer decks, fewer services, and more back to the basics. The change could be similar to what happened to airlines after the 1970's and 1980's – luxury was quite much removed, and if one desired to have it, later on, business ticket prices differed rather substantially from ordinary ones. This possible shift will also mean a change in routes, where time will be more critical than enjoyment, services and cruising.

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Appendix 1. Regression model of total passenger transportation volume in Finnish seaports (1970–2021), where it is explained with time (year) and Covid-19 (binary) variables.

SUMMARY OUTPUT

<i>Regression Statistics</i>					
Multiple R	0.978				
R Square	0.956				
Adjusted R Square	0.955				
Standard Error	1118729				
Observations	52				

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	2	1.34438E+15	6.7219E+14	537.084	4.71965E-34
Residual	49	6.13262E+13	1.25155E+12		
Total	51	1.40571E+15			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	-687333715.4	21866656.9	-31.433	3.86922E-34
Year	350729.0	10963.2	31.992	1.69776E-34
Covid-19	-14863808.6	855603.8	-17.372	1.38632E-22

Appendix 2. Regression model of unitized sea freight volume between Finland and Sweden ('000 tons), where it is explained with time (year) and Covid-19 (binary) variables.

SUMMARY OUTPUT

<i>Regression Statistics</i>				
Multiple R	0.229			
R Square	0.053			
Adjusted R Square	-0.034			
Standard Error	873.55			
Observations	25			

ANOVA				
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>Significance F</i>
Regression	2	931692.4	465846.2	0.610
Residual	22	16788133.9	763097.0	0.552
Total	24	17719826.3		

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	19765.4	55126.2	0.359	0.723
Year	-7.4	27.5	-0.268	0.791
Covid-19	-598.5	729.7	-0.820	0.421

Appendix 3. Regression model of unitized sea freight volume between Finland and Estonia ('000 tons), where it is explained with time (year) and Covid-19 (binary) variables.

SUMMARY OUTPUT

<i>Regression Statistics</i>					
Multiple R	0.987				
R Square	0.974				
Adjusted R Square	0.971				
Standard Error	264.88				
Observations	25				

<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	2	56801624.3	28400812	404.781	4.44435E-18
Residual	22	1543594.7	70163.4		
Total	24	58345219.1			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	-411254.1	16715.7	-24.603	1.69E-17
Year	206.1	8.3	24.762	1.47E-17
Covid-19	160.0	221.3	0.723	0.477

Appendix 4. Regression model of combined revenue of three ropax operators serving Finland, where it is explained with time (year) and Covid-19 (binary) variables.

SUMMARY OUTPUT

<i>Regression Statistics</i>				
Multiple R	0.851			
R Square	0.724			
Adjusted R Square	0.684			
Standard Error	216269			
Observations	17			

<i>ANOVA</i>				
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>Significance F</i>
Regression	2	1714687826897	857343913448	18.330
Residual	14	654814651539	46772475110	0.0001
Total	16	2369502478436		

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	-103498530.4	25981111.3	-3.984	0.001
Year	52205.3	12913.0	4.043	0.001
Covid-19	-1177540.1	196346.3	-5.997	0.000

Notes to Contributors

Manuscript. Submissions should be clear and concise. Manuscripts will be accepted with the understanding that their contents are unpublished and not being submitted for publication elsewhere. All parts of the manuscript, including the title page, abstract, tables and legends should be typed in English. Allow margins of at least 3cm on all sides of typed pages. Pages must be numbered consecutively throughout the paper.

Title. Must be as brief as possible and consistent with clarity (6 to 12 words). Authors should also supply a shortened version of the title suitable for the running head, not to exceed 50 character spaces.

Author Affiliation. Include the full names of authors, academic and/or professional affiliations and the complete mailing address of the author to whom proofs and correspondence should be sent as well as the address information of all of the authors.

Abstract. Each paper should be summarized in an abstract of not more than 150 words. Avoid abbreviations, diagrams and references to the text.

Key words. Authors must supply three to five keywords or phrases which identify the most important subjects covered by the paper.

Mathematical Notation. Use only essential mathematical notation as it is costly to typeset and may limit readership. Where mathematical notation is essential, keep it simple and in conformance with conventions of the profession.

References. Citations within the text must include the author name(s) and the data in parentheses [i.e., Smith, Jones, and Cutler (1993)]. Use et al. in the text only when four or more authors are cited. Do not use et al. in the references. Alphabetize the reference section and include all text citations. For more information, consult the *Chicago Manual of Style*. Follow these examples:

- **Journal** - Koenig, E. F. (1984) Fisheries Regulation Under Uncertainty: A Dynamic Analysis. *Marine Resource Economics* 1(2):193-208.
- **Book** - Heaps, T. and Helliwell, J. F. (1985) *The Taxation of Natural Resources. Handbook of Public Economics*, Vol. I, Auerback, A. J. and Feldstein, M. (eds.), pp. 21-72. Amsterdam: North-Holland.

Data and Documentation. Data sources, models and estimation procedures are expected to be documented to permit replication by other researchers. Data used in the analyses should be made available to other researchers for replication purposes. Submission of appendices, model documentation and other supporting materials is encouraged to facilitate the review process.

The Ethical Guidelines

Preamble.

The KMI International Journal of Maritime Affairs and Fisheries (hereinafter referred to as the "the journal", www.kmij.org) is a peer-review journal of ocean policy studies and marine data analytics. The journal offers researchers, analysts and policy makers a distinct combination of legal, political, social and economic analyses. The journal covers a range of international, regional and national marine policies; management and regulation of marine activities including fisheries, ports and logistics; marine affairs, which encompasses the topics of marine pollution and conservation as well as the use of marine resources. Editors of the journal are responsible for organizing and keeping guidelines of reviewing and accepting manuscripts submitted to the journal.

1. General rules

- The guidelines describe measures to set up ethics and hinder malpractices in management of the journal.
- The guidelines apply to those who join the publication of the journal.
- The terms are defined as follows.

Forgery implies the behavior of distorting data.

Falsification implies the behavior of twisting the truth of research performance or findings by deforming research findings, processes, devices, etc., artificially transforming or deleting data arbitrarily.

KMI is an initialism for the Korea Maritime Institute.

Plagiarism implies the behavior of borrowing the concepts, research facts, results, etc., of other people without proper references or notations.

Display of unjustified manuscript and paper authors implies the behavior of granting authorship to a person who has not given or made technical or scientific contribution to the content or results of research.

Double publication implies the act of publishing texts identical or similar to two or more academic journals.

Self-plagiarism implies a sort of **Plagiarism** in which an author republishes a previous work entirely or partially without referring to the previous publication.

The guidelines refer to the Ethical Guidelines.

2. Ethical rules for editors

- **Liability of editors:** Editors should be responsible for deciding whether to respect authors' character, independently as scholars, and publish submitted manuscripts and papers.
- **Fairness of paper treatment:** Editors should treat manuscripts and papers fairly on the basis of manuscript and paper quality and the Ethical Guidelines regardless of gender, age, nationality, organization, prejudice, or private relationship.
- **Objectivity of reviewer selection:** Editors should assist the reviewers utilizing their expertise and fair judgment to evaluate submitted manuscripts and papers. Editors should ensure manuscripts and papers evaluated as objectively as possible by avoiding the reviewers who may have an antagonistic or positive bias towards certain authors.
- **Non-exposure of the manuscripts and the paper review process:** Editors should not expose information on authors or submitted manuscripts and papers to persons except reviewers until it is decided whether to publish the manuscripts and papers.

3. Ethical rules for reviewers

- **Honesty and punctuality of manuscript and paper review:** Reviewers assigned to assess should evaluate the manuscripts and the papers reliably and give notice of the results to editors within a certain period of time. When considering themselves disqualified for review, reviewers should inform editors of the fact without hesitation.
- **Impartiality of manuscript and paper review:** Reviewers should review the manuscripts and papers evenly in accordance with the objective criteria. The reviewers should not depreciate the manuscripts and the papers without sufficient basis or refuse them for the reason of colliding with their own views or interpretations.
- **Validity of manuscript and paper review:** Reviewers should respect the intellectual tendency of the author. The reviewers should clarify their judgments and explain in detail the reasons for supplementation in an evaluation sheet, if necessary.
- **Confidentiality of review and disallowance of prior citation:** Reviewers should maintain confidentiality of the contents within the manuscripts and the papers. Except when seeking special advice for evaluation, it is recommended that reviewers do not show manuscripts and papers to others or discuss them on any level. Additionally, reviewers should not cite manuscripts and papers without authors' consent before the publication of the journal that includes the manuscripts and the papers.

4. Ethical rules for authors

- **Research wrongdoing:** Authors are not allowed to forge, falsify or pirate manuscripts and papers, or display unreasonable authorship.
- **Double publication:** Authors are not allowed to submit the studies previously published, nor those set to be published, nor those under review to other academic journals or

publications. This principle does not apply to manuscripts and papers presented at research conferences, research reports, dissertations, nor those openly unpublished, etc. In this case, the fact should be notified to editors and readers.

- **Citation:** Academic materials should be cited precisely and along with their clear and distinct sources. Data privately obtained should be cited only after receiving agreement from the person who produced the information. If the writings or ideas of others are cited or borrowed, respectively, the fact must be specified using footnotes.

5. Enforcement guidelines for research ethics

- **Vow of ethics keeping:** Authors who submit their manuscripts and papers to the KMI or are entrusted with manuscript review and paper review will be considered to have pledged to keep these guidelines.
- **Report of ethics violation:** If authors or reviewers have violated research ethics, the editor-in-chief of the journal as a representative of KMI should rectify the problems involving processes or results. If any problem has proved to be a clear violation of research ethics, the case should be assigned to the Ethics Committee of the journal. The editor-in-chief of the journal nominates the Director and four members of the Ethics Committee of the journal.
- **Composition and convocation of the Ethics Committee:** The Director should convene a meeting of the Ethics Committee within 7 working days after the appointment of the Director and the four members. The Director should be the Chair of the Ethics Committee meeting.
- **Request for attending and material submission:** The Ethics Committee may request informer and suspect to submit materials and to attend its meeting. In this case, suspects should accept the request. The very non-acceptance of suspects violates research ethics.
- **Right protection and confidentiality of informer and suspect:** The identities of informer shall not be disclosed to any third person directly or indirectly. Care should be taken lest the suspects' honor or rights should be infringed on until verification is completed on whether they are involved in any wrongdoing.
- **Judgement of the Ethics Committee meeting:** The Ethics Committee meeting can discuss with more than half of the members present and vote on the contents and results with two-thirds of the members or more present.
- **Report of the Ethics Committee meeting:** The Director shall prepare a results report of the Ethics Committee meeting and submit the result to the editor-in-chief of the journal in five working days following the judgement.
- **Notice of the judgement and decision of editor-in-chief to the author:** The editor-in-chief of the journal shall accept the **Judgement** of the Ethics Committee meeting if any prejudice or private interest of the Ethics Committee is not found. The **Judgement** of the Ethics Committee includes ethics violation, measures and sanctions for the ethics violation. The editor-in-chief of the journal shall notice **the judgement** of the Ethics Committee and the final decision of the editor-in-chief **to the author** in five working days after the arrival of the judgement. If the editor-in-chief of the journal finds any prejudice or private interest

of the Ethics Committee, the editor-in-chief re-appoints the Director and four members of the Ethics Committee of the journal.

- **Opposition of the author:** If the author or the information provider of the **ethics violation is not satisfied with the judgement of** the Ethics Committee and the decision of the editor-in-chief, the author or the information provider may file up the objection to the editor-in-chief. In that case, the editor-in-chief shall give notice of the objection to the Director within 7 working days after the filing. The Director shall review the case within 12 working days after notice is given by the editor-in-chief.
- **Measures and sanctions for ethical violations:** The Ethics Committee shall apply measures and sanctions in accordance with the types, contents, and degrees of the intention of ethical violations, such as amendment or prohibition of publication in the journal, cautions or warnings, and restrictions of submission of an article to the journal.

6. Date of Enforcement

The guidelines shall come into effect as of the 29th of May, 2021.

