Handelshøyskolen BI

GRA 19703 Master Thesis

Thesis Master of Science 100% - W

Predefinert informasjon

Startdato:	16-01-2022 09:00	**Termin:**	202210
Sluttdato:	01-07-2022 12:00	**Vurderingsform:**	Norsk 6-trinns skala (A-F)
Eksamensform:	T		
Flowkode:	202210||10936||IN00||W||T		
Intern sensor:	(Anonymisert)		

Deltaker

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Informasjon fra deltaker

Tittel *:	The impact of COVID-19, the Suez Canal blockage and the War in Ukraine on the container shipping industry and an analysis of how to prepare for disruptions in the future
Navn på veileder *:	Eirill Bø

Inneholder besvarelsen konfidensielt materiale?:	Nei	**Kan besvarelsen offentliggjøres?:**	Ja

Gruppe

Gruppenavn:	(Anonymisert)
Gruppenummer:	171
Andre medlemmer i gruppen:	

Master thesis

The impact of COVID-19, the Suez Canal blockage and the War in Ukraine on the container shipping industry and an analysis of how to prepare for disruptions in the future

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Hand-in date:
01.07.2022

Campus:
BI Oslo

Examination code and name:
GRA 19703 Master Thesis

Program:
Master of Science in Supply Chain and Operations Management

Table of Contents

Figure index

Acknowledgement

We would like to thank and acknowledge supervisor Eirill Bø, who has dedicated her time, given valuable feedback and support throughout the process. Your involvement in supervising our thesis has been vital for the research and we will be forever grateful for the collaboration.

Further, we would like to thank our families and loved ones for their support and encouragement throughout the master thesis and study period at BI Norwegian Business School.

Thank you,
Erlend Alexandersen Dahlberg
Erlend Vangdal

Abstract

The container shipping industry is considered the backbone of global trade and is therefore of severe importance for our globalised business world. COVID-19, the Suez Canal blockage, and the War in Ukraine are unprecedented events in modern history and indisputably impacted the worldwide flow of goods. The authors have analysed how these disruptions have impacted the container shipping industry. Further, the thesis discusses how the industry could have dealt with the issues that followed and be better prepared for new situations like these in the future.

This master thesis has used a qualitative research method to answer the research question: *How have disruptions such as COVID-19, the Suez Canal blockage and the War in Ukraine influenced the container shipping industry, and how can the industry prepare for disruptions in the future?* To answer this, data were collected entirely through literature. The theoretical background, which consists of SCM, disruptions, SCRM, resilience, reliability and industry 4.0, forms the basis and builds evidence for the analysis and discussion. The study has shown how dependent the flow of worldwide goods is on well-functioning container shipping and how vulnerably it is to external disruptions. Our findings revealed how reliable the industry is on human workforce. During the pandemic, the lack of workers caused massive bottlenecks in the ports and created container shortages in the industry. Consequently, the container freights rates spiked and the reliability in the industry decreased.

The main conclusion that can be drawn from this study, is that industry 4.0 technologies could enhance SC and container shipping performance when experiencing unexpected disruptions. Applying technologies could increase the efficiency, transparency and collaboration between SC entities, something that increases reliability and resilience, and better prepare the industry for future disruptions.

Chapter 1 – Introduction

1.1 Motivation

In the era of globalization, maritime transport and container shipping have been and are the backbone of global trade and the global economy (United Nations, 2016). This, referring to maritime transport and container shipping, low-cost and efficient way of transporting is vital for growth and development in the world (United Nations, 2016), and maritime logistics is responsible for the carriage of around 90 percent of the world trade (Global Infrastructure Hub, 2020; MaritimeInfo, 2020; Ng et al., 2016). The container shipping industry is essential for the global economy because of its critical role in intercontinental trade and the import/export of affordable food and manufactured goods (MaritimeInfo, 2020). Shipping is also considered the safest and most environmentally friendly form of commercial transport (Ng et al., 2016).

With a more interlinked and global economy, the maritime industry experiences more challenges, but also more opportunities than before (Zhou et al., 2018). Technological, environmental, and geopolitical challenges, as well as worldwide disruptions, will test the resilience of the maritime sector over the coming decades. COVID-19 is a classic example of a global disruption influencing and tangibly testing resilience. The COVID-19 pandemic is considered the most severe global crisis since the Second World War (Borrell, 2021), and global SCs, highly dependent on container shipping, have experienced massive disruptions caused by the pandemic. Out of the 90 percent of the global trade transported by sea, 60 percent is carried out in large container ships (Nagurney, 2021). Hence, disruptions in the container shipping industry have a significant impact on SC reliability.

As the pandemic hit, countries and governments implemented national lockdowns and restrictions to deal with the risk of infection. Closed borders and ports, in addition to quarantine requirements, significantly influenced the industry's throughput. Fewer people at work and sometimes closed terminals substantially impacted the shipping industry by decreasing efficiency and increasing lead time (Youd, 2021). Consequently, the industry experienced increased prices for container space, shortages of containers, and delays – harming companies and negatively affecting consumers.

In addition to the pandemic, the industry experienced disruptions as one of the world´s largest container ships, Ever Given, blocked The Suez Canal for 6 days in March 2021. The Suez Canal is connecting some of the most essential routes in the container shipping industry, and as much as 30 percent of all global container traffic passes through the Canal (New Zealand Ministry of Foreign Affairs and Trade, 2021). The blockage became an additional disturbance when the industry was still trying to cope with the challenges of the pandemic.

Another more recent disruption is the War in Ukraine, where Russia invaded Ukraine on February 24 this year. This has created further issues that prolonged the industry's recession. At the same time, Russian forces shut off shipping routes, and logistics companies suspended their services due to the war (Tan, 2022). These aspects, together with Ukrainian ports being closed, damaged, or under attack, have further increased the problems in the shipping industry, testing both reliability and resilience.

None of the mentioned disruptions was supposed to happen, and when they occur almost simultaneously, it showed how vulnerable the global SC is. It is impossible to anticipate when the next disruption will appear and how it will affect, however, the industry should do everything to prepare itself. The pandemic has shown how dependent the industry is on the human workforce, hence finding something that can reduce this dependency is a suggested way of preparing the industry. With the use of industry 4.0 technologies, companies could replace some of the main processes that now are strongly dependent on the human workforce, ultimately resulting in the disruptions having less impact on the total global SC.

The maritime industry was already before the pandemic to some extent introducing industry 4.0 technologies, including Artificial Intelligence, robotics, blockchain, the Internet of Things, 5G and big data (de la Peña Zarzuelo et al., 2020). All these technologies will probably have significant importance for the industry's further development, especially regarding environmental impact, efficiency, and lead times. This paper investigates how the mentioned technologies can help the container shipping industry prepare itself for disruptions in the future.

1.2 Research question

The overall aim of this thesis is to investigate the impact disruptions have on the container shipping industry and examine how the industry could be better prepared for disruptions in the future. The three biggest disruptions that have influenced the industry in the last years are COVID-19, the Suez Canal blockage, and the War in Ukraine. All are covered considerably in the media, however, research on the actual effect it has had on the container shipping industry has not been enclosed. Following the understanding of how the disruptions have influenced the industry, the topic of preparedness for future disruptions arises. The research question in this paper is hence: *How have disruptions such as COVID-19, the Suez Canal blockage and the War in Ukraine influenced the container shipping industry, and how can the industry prepare for disruptions in the future?*

1.3 Value of research

This paper addresses some of the most discussed topics over the last years, COVID-19, the Suez Canal blockage, and the War in Ukraine. There is no doubt that the disruptions have influenced in a significant matter, however, how much the total effect has been on the container shipping industry, is yet to discover. This research aims to investigate the effects and connect the data into one paper. Moreover, the research proposes how the industry can be better prepared for disturbances in the future, by examining how to improve risk management and increase reliability and resilience in an SC.

1.4 Structure of the paper

This thesis is divided into six chapters. The introduction is the first chapter, followed by the research methodology. In the research methodology, the conceptual framework is introduced, before the research strategy and design, data collection, data analysis and quality of research are reviewed. Chapter three, the theoretical background provides insight into relevant theories and aspects to substantiate the analysis, discussion, and conclusion. The theoretical background review SCM and container shipping industry, disruptions, SCRM, resilience, reliability and lastly industry 4.0. After the theoretical background, the chapter about findings and analysis is presented. This part touch upon increased demand, closed borders and

ports, lack of drivers, container shortages, increased prices, resilience and reliability. While the findings and analysis answer part one of the RQ, the discussion in chapter five examines the second part of the RQ with regards to the findings and theoretical background. The final chapter is the conclusion, which also contains research limitations and suggestions for future research.

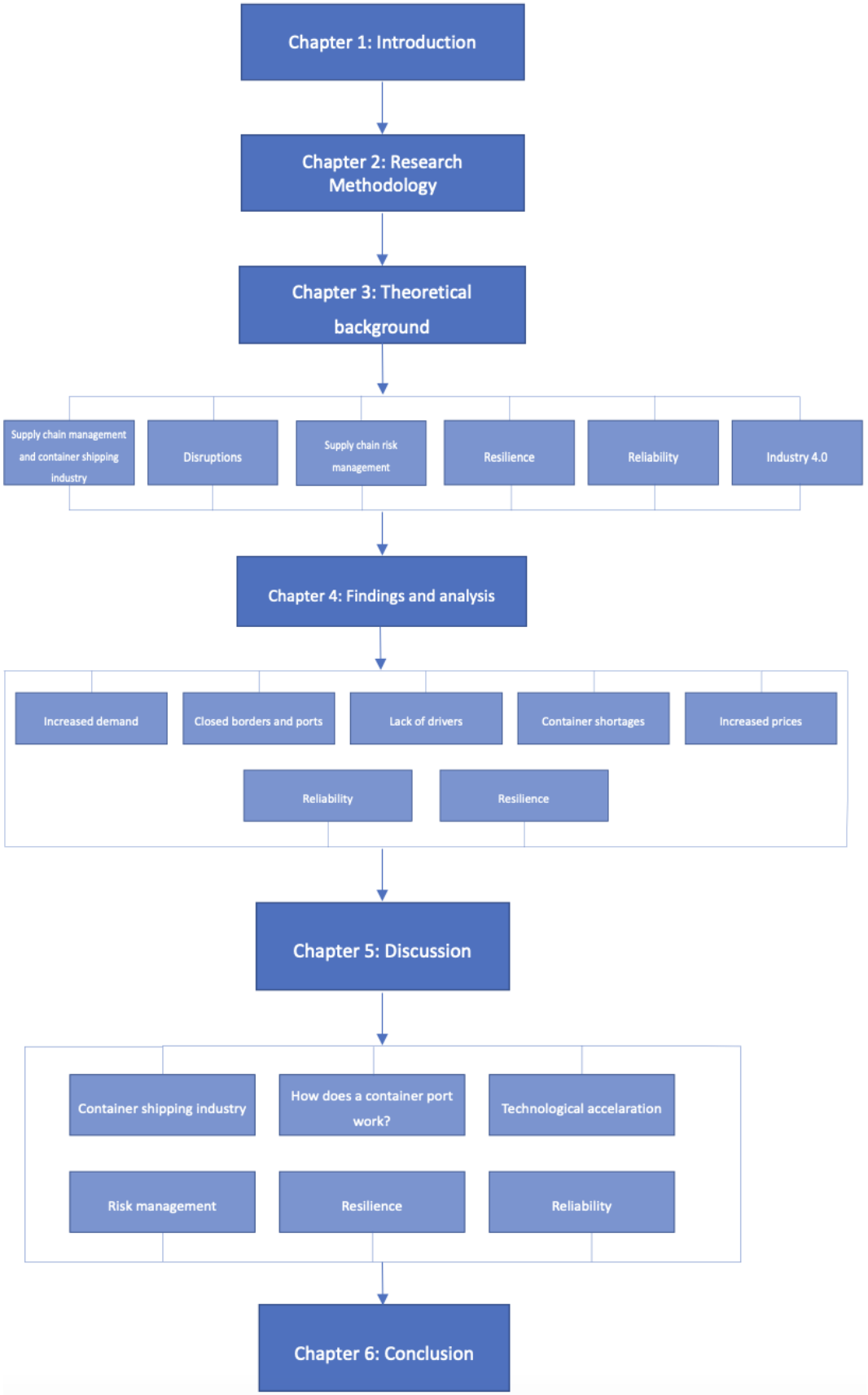

Figure 1: Structure of the paper

Chapter 2 - Research Methodology

The methodology is designed to assess how disruptions like the COVID-19 pandemic, the Suez Canal blockage and the War of Ukraine have influenced the container shipping industry. Moreover, it will assess how the industry can better prepare itself for future disruptions. A suggested framework has been developed to guide the research in the right direction (Figure 2).

2.1 Conceptual framework

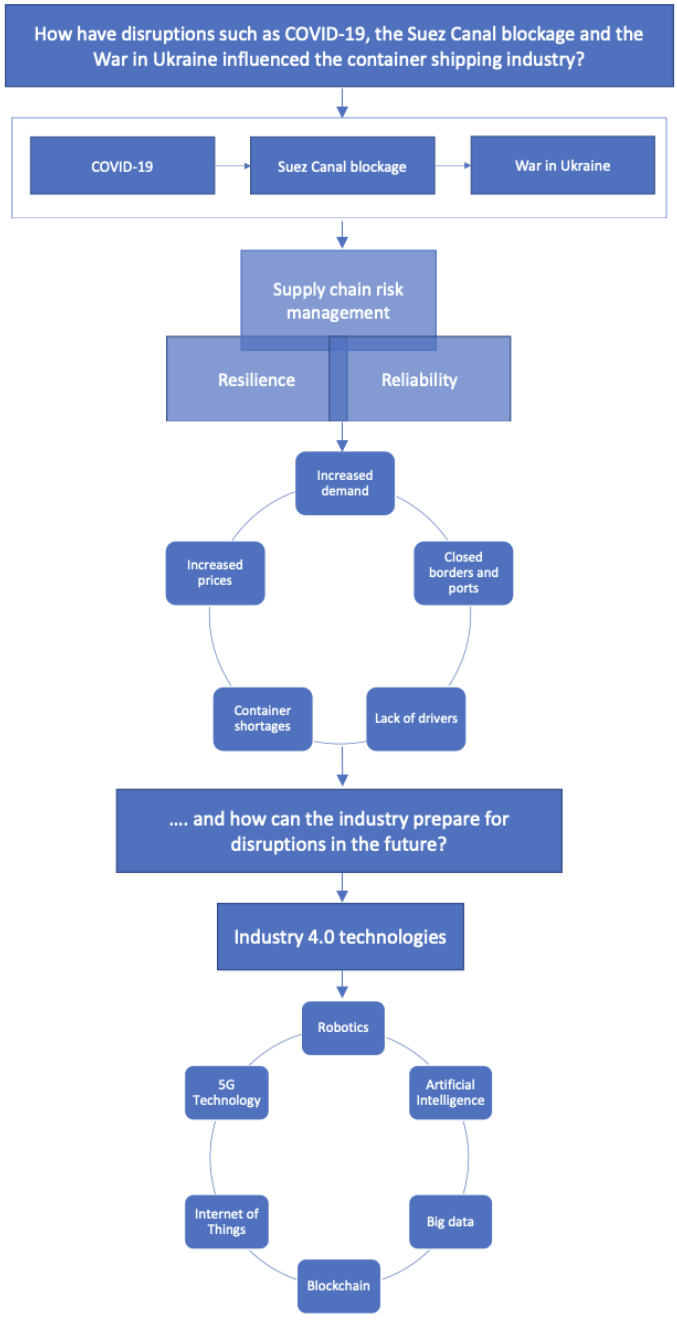

Figure 2: Conceptual framework

The framework has helped to avoid the risk of the collected data and results not illuminating the research question. The framework was developed through thorough considerations about what information was necessary to answer the research question. Three theoretical models; SCRM, resilience, and reliability, have been used in the analyses to assess how COVID-19, the Suez Canal blockage and the War of Ukraine have influenced the container shipping industry. All the models are linked together and build a foundation for the analyses and discussion. Lack of truck drivers, increased demand, closed borders and ports, container shortages and increased prices for container space are some of the key implications that have emerged from the mentioned disruptions. Furthermore, the paper assesses how the industry can prepare for disruptions in the future. More specifically, it discusses how industry 4.0 technologies can help to manage risks and increase resilience and reliability in the container shipping industry.

2*.2 Research Strategy*

Conducting research is about collecting relevant data on a specific subject and analysing it to generate knowledge, and the collected data creates a theoretical understanding of the subject (Bell et al., 2019a, p. 19). Research can be approached through quantitative, qualitative, or mixed-method. Quantitative and qualitative research is the primary research strategies and is used as general approaches when conducting research. Quantitative data are based on the collection of numerical data, while qualitative data is based on the collection of data that compresses written or spoken words and images (Bell et al., 2019). To answer the research question and reach the objective, this paper has through a qualitative research approach, developed an in-depth understanding of the research area. Qualitative data is sufficient to answer the research question, and quantitative data is hence not considered necessary in this paper.

2.3 Research design

The choice of research design is an important aspect when doing research, and the selection reflects decisions about which priorities are given to the dimensions of the research process. Research design provides a framework for the collection and analysis of data. Research design is linked to the research method, which is a

technique for collecting data. The choice of research method reflects on which instruments and techniques to be used. Both research method and research design are connected to the choice of research strategy and the research questions (Bell et al., 2019). This paper uses a textual approach, where various retrospective material treats researchers' observations and written documents as texts.

2.4 Data collection

Data collection is the key point of any research project and the method of collecting data depends on the research question and the level of data accessibility (Bell et al., 2019). It is essential to gather data that helps answer the research question. Because of the high relevance, there already exists a lot of data on the suggested study. This paper uses naturally occurring retrospective and archival qualitative data, including research articles, newspaper reports, and corporate and government documents.

The research will rely entirely on secondary data that already exist and have been collected by others. Collecting primary data can be a very time-consuming process, and secondary data is, therefore, an excellent option for collecting data when time is of essence. When writing a master thesis, there is limited time for collecting data, and the use of secondary data is hence beneficial. Moreover, when collecting primary data through interviews and observations, there is a need for collaboration with different people, which is also quite time-consuming. More importantly, there is already a lot of available data on this topic, and the need for primary data is, therefore, less important to answer the research question.

Secondary data was gathered from literature containing findings and theories related to the study. The literature review is a crucial part of a master thesis and provides the basis for justifying the research question (Bell et al., 2019, p. 91). Using existing literature is a means of developing arguments about the significance of the research and where it leads (Bell et al., 2019, p. 91). The Literature review begins by providing general information about Supply chain management (SCM) and maritime logistics, with a focus on the container shipping industry, to create a foundation for further research. Furthermore, disruptions were introduced and literature containing risk management, resilience and reliability was collected.

To get an overview of how the industry uses technologies today, relevant information about the current situation in the container shipping industry was gathered. In addition, some organisational documents were used in this study.
Organizational documents are a heterogeneous group of sources of particular importance to business and management researchers (Bell et al., 2019, p. 550). This paper uses some annual reports from shipping companies and ports in its research. These reports consist of important information about how COVID-19, The Suez Canal blockage and the War in Ukraine have influenced their company and the industry in general. States and countries also source a great deal of information of potential significance for business researchers (Bell et al., 2019, p. 48). Governmental documents have provided information about COVID-19 restrictions, quarantines, and closed borders and ports in different countries.

2.5 Data analysis

The next stage in the research methodology is to analyse the data collected, referred to as data analysis. The analysis is fundamentally about data reduction, where all gathered information is reduced to be able to make sense of it (Bell et al., 2019, p. 12). The collected and analysed data in this study is based on a theoretical background provided as secondary data.

In the analyses and discussion, the objective was to answer both parts of the research question. We first investigated how disruptions like COVID-19, the Suez Canal blockage and the War in Ukraine have influenced the container shipping industry. Some of the key takeaways from the analyses were the lack of truck drivers, closed borders and ports, container shortages, and increased prices. Moreover, the paper investigates the current situation of 4.0 technologies in the industry, before it investigates how the same technologies can make the industry more resilient and prepared for disruptions in the future.

2.6 Quality of research

When doing research, it is essential that you can trust and rely on the data that has been collected. Validity is a criterion for evaluating business research and is in many ways the most important one (Bell et al., 2019, p. 46). Validity is about how valid the research done is and is concerned with the integrity of conclusions

generated through the research (Bell et al., 2019, p. 46). The collection of secondary data can be difficult to analyse in terms of accuracy, and the quality of mass-media outputs can be difficult to determine. While the outputs usually can be seen as genuine, the authorship of articles is often unclear (for example, editorials and some magazine articles) (Bell et al., 2019, p. 552). Hence, it can be challenging to know if the account can be relied upon as being written by someone in a position to provide a correct version (Bell et al., 2019, p. 552). However, finding several articles arguing the same thing helps in terms of the validity of the findings. In addition, this paper is written with a critical assessment of the sources and only uses well-known web pages when collecting data. This helps ensure the quality and validity of the study.

Chapter 3 – Theoretical background

In this chapter, the theoretical background will connect research with existing theories and be used to answer the research question: *How have disruptions such as the COVID-19 pandemic, the Suez Canal blockage and the War in Ukraine influenced the container shipping industry, and how can the industry prepare for disruptions in the future?* Some main topics and concepts identified from the literature are considered crucial for the next parts of the paper. First, the paper introduces Supply chains (SC) and Maritime logistics with a focus on the container shipping industry. Furthermore, the paper elaborates on disruptions in SCM, before important concepts of risk management, resilience, and reliability are presented. Lastly, literature about industry 4.0 is introduced to build the foundation to answer the last part of the research question.

3.1 Supply chain management and container shipping industry

To describe SCM, a brief introduction to SCs is necessary. Christopher (2016, p. 3) described SCs as "A network of connected and interdependent organizations mutually and cooperatively working together to control, manage and improve the flow of materials and information from supplier to end-users". SCM involves the management of upstream and downstream relationships with suppliers and customers in a broad network of people and businesses (Christopher, 2016, p. 3).

Globalization has made modern SCs much more complex than traditional SCs, with multidimensional problems set with a virtually endless number of variables for optimization (Kordic, 2008). In addition come technological improvements within SCM enabling SCs to become strategic weapons that can help to avoid disruptions within the SCs (Kordic, 2008). At the same time, SCM is focused on the management of relationships to achieve profitable and better outcomes for all parties involved (Christopher, 2016). This shift, together with the increased turbulence and volatility creates greater uncertainty in SCs (Christopher, 2016). As a result of this, new factors become important in SCM for businesses to stay competitive.

The maritime industry is a vital link in the global SC, with more than 90 percent of international trade being carried by ships (MaritimeInfo, 2020; Ng et al., 2016). Out of the 90 percent of the global trade transported by sea, 60 percent is carried in large container ships (Nagurney, 2021), showing how important the industry is for global trade. Container ships are oceangoing vessels designed to transport large, standard-sized containers and huge quantities at the same time (Jha, 2021). Container ships have revolutionized the freight of products globally by assuring the safety and security of the transported cargo supplies (Jha, 2021). To handle large containers, container terminals have become a crucial intermediate in the SC. Ports have traditionally been cultural and economic centres of cities and their surroundings (Ng et al., 2016). Container terminals are logistics platforms where containers are stored, and transferred from one transport modality to another (Placa, 2020). Containers are built based on the International Organization for Standardization´s standards and are designed to carry bulk. Because containers have been standardized, the terminals allow goods to be handled quickly, safely, and efficiently (Placa, 2020).

3.2 Disruptions

Disruption is widely defined as the action of preventing something, especially a system, process, or event from continuing as usual or as expected (Cambridge Dictionary, n.d.). External disruptions are considered a huge risk for companies, especially within the SC industry, and Heckmann et al. (2015, p.121) defines risk as the "… probability of occurrence of disruptive events". Looking at it from an

economic and financial perspective, disruptions are events negatively impacting SCs (Luke & Rodrigue, 2008).

Todays business world is more complex, globalized, and technologized than ever before, and as a consequence, the vulnerability of SC disruptions increased (Christopher, 2016). The COVID-19 pandemic, the Suez Canal blockage, and the War in Ukraine occurred almost at the same time significantly impacting the container shipping industry. External risks like the mentioned disruptions could separately cause a significant decline in economic activity, and together the impact could be even more significant. Recessions could vary from a light decline for a few months to a steep decline lasting for years (Notteboom et al., 2021). The extent of the recession will imply various levels of decline in consumption, trade, and transportation activity as shown in figure 3 (Notteboom et al., 2021).

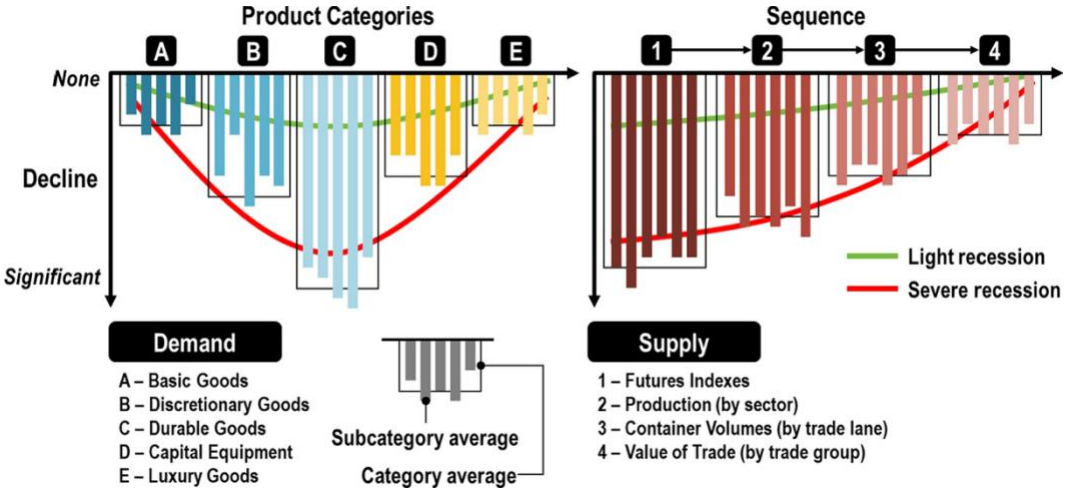

Figure 3: Demand and supply impacted by recessions (Notteboom et al., 2021)

3.3 Supply chain risk management

Because of the increased experience of disruptions in SCs, the concept of SCRM (SCRM) has become a key area of interest. With SCRM companies aim to reduce the likelihood and severity of potential risk scenarios that could occur in SCs. Earlier research within the area of SCRM shows that researchers have multiple risk definitions for different parts of the SC (Ho et al., 2015). Ho et al. (2015, p. 5) define SC risk (SCR) as: "the likelihood and impact of unexpected macro and/or micro-level events or conditions that adversely influence any part of the SC leading to operational, tactical, or strategic level failures or irregularities". Following this, as

well as the definition of SCM risk and risk management must relate to the overall supply network and how all parties involved react and work together in times of unexpected events.

Companies often focus on business continuity within the individual business, despite this, it can be argued that the biggest risk to business continuity often is in the wider network where the individual business is just a part (Christopher, 2016, p. 219). Therefore, Christopher (2016, p. 220) suggests widening the focus on SC vulnerability with the use of an SC risk profile for each company. This profile seeks to establish where the greatest vulnerabilities are and what the probability of disruption is. Creating the view of SC risk as shown below.
SC risk = Probability of disruption X Impact (Christopher, 2016, p. 220). With the creation of this risk profile, companies attempt to seek out the critical paths through their networks, with the use of risk management (Christopher, 2016).

Within SCRM literature identifies four sources of risk across supply networks, namely supply risk, process risk, demand risk, and control risk (Christopher, 2016; Christopher et al., 2011). These risks are connected as shown in figure 4.

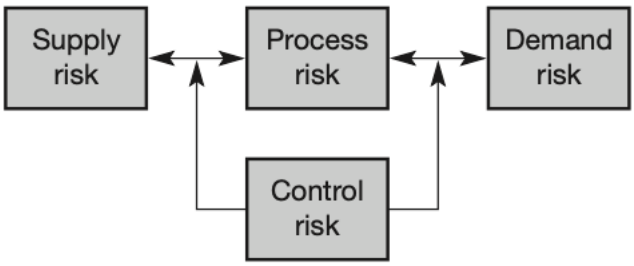

Figure 4: Supply network risks (Christopher, 2016, p. 221).

In times of disruptions, companies focus mainly on the supply risk, demand risk, and control risk (Notteboom et al., 2021; van Hoek, 2020). Supply risk refers to how vulnerable businesses are to disruptions in the supply (Christopher, 2016). Moreover, supply risk increases with the increase in global sourcing, poor supply management, and reliance on key or single suppliers (Christopher, 2016). Global sourcing is at the heart of the container shipping industry, substantiating the risk assessment of supply risk. Demand risk refers to how volatile demand is, and spikes in demand and consequent bottlenecks are identified as the main demand risks when

experiencing disruptions (Christopher, 2016; Sturlason, 2022; van Hoek, 2020). Lastly, we have control risk, which refers to how likely disturbances and distortions are to be caused by the company's own internal control systems (Christopher, 2016). During disruptions, the ability to engage the whole supply network will be an important factor to handle and control risk. In the literature four aspects for the development of SCRM are identified; risk identification, risk assessment, risk treatment and risk monitoring (Ho et al., 2015; Neiger et al., 2009; Tummala & Schoenherr, 2011).

First step: risk identification involves the identification of risk types, risk factors, or both. To implement SCRM successfully, managing risk, identifying all relevant risks, and recognizing future uncertainties are all crucial aspects (Fan & Stevenson, 2018; Ho et al., 2015; Neiger et al., 2009). Understanding the SCs and risk awareness is necessary to manage and mitigate risk successfully (Christopher, 2016; Heckmann et al., 2015).

Second step: risk assessment is focused on the severity and probability of an event occurring (Ho et al., 2015). Further, it is based upon the assessment of relevant data, expert opinions, or scenario thinking, something that in order lays the foundation for the two next steps (Fan & Stevenson, 2018).

Third step: risk treatment is about using different strategies to reduce risk to acceptable levels (Manuj & Mentzer, 2008; Neiger et al., 2009). Christopher (2016) states that risk mitigation plans could be put into two broad categories, namely redundancy and flexibility. These aspects are important for successful risk mitigation within companies.

Fourth step: risk monitoring focuses on the importance of controlling identified risks to be prepared if their status changes, and to reduce the frequency and impacts of SC risks (El Baz & Ruel, 2021; Fan & Stevenson, 2018).

Disruptions such as COVID-19, the Suez Canal blockage and the War in Ukraine all test the resilience and robustness of SCs. Therefore, reconfiguration and deployment of resources/capabilities with the use of the four SCRM steps could

help cope with the impact of disruptions and have positive effects on the robustness and resilience (El Baz & Ruel, 2021).

3.4 Resilience

Resilience is a key aspect of SCM theory, which in SC terms is defined by Christopher (2016, p. 232) as "the ability of a system to return to its original or desired state after being disturbed". Another definition from Ponomarov & Holcomb (2009, p. 131) is "the adaptive capability of the SC to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function".

In a market characterized by higher levels of turbulence and volatility, and an increase in unexpected shocks and disruptions, resilient SCs are more important than ever (Christopher, 2016). Resilient SCs manage the critical nodes, such as dependence on a single supplier, or a bottleneck in the process in a satisfactory way (Christopher, 2016). SCs must be designed to deal with disruptions, provide an efficient and effective response, and be capable of recovering to their original structure or better post the disruption (Ponomarov & Holcomb, 2009). All together this is the essence of the important aspect of SC resiliency. COVID-19, the Suez Canal blockage, and the War in Ukraine are unexpected events causing disruptions and testing the resilience of SCs and the container shipping industry.

Achieving resilience in SCs means being agile and flexible, and by this being able to change quickly when meeting disruptions (Christopher, 2016). SC agility and responsiveness are the ability to respond to customer requirements in even shorter time frames, as well as the ability to sense changes and respond to them rapidly and flexibly (Christopher, 2016; Gligor & Holcomb, 2012; Li et al., 2008, 2009). Agility has become more important than traditional long-term planning, something being emphasized when global SCs experience disruptions and inappropriate events they must deal with. For the future companies must be much more demand-driven than forecast-driven, a transition that has to be made through agility across the supply network (Christopher, 2016). Jüttner & Maklan (2011) focus on four central components regarding SCR: collaboration, visibility, flexibility and velocity.

Collaboration across SCs is more important than ever before due to more integrated global chains. A more globalized business world has changed the way companies compete. The traditional way of competing as isolated and independent entities is no longer possible. Today companies compete in the era of "SC competitions", meaning competition as a connected entity (Christopher, 2016). Following this development, the importance of collaboration and transparency across actors in SCs has increased significantly, especially to achieve SC resilience (Christopher, 2016; Jüttner & Maklan, 2011; Pettit et al., 2013). A high level of collaboration between SC partners and viewing the chain with a comprehensive perspective will help build resilience in the chain (Christopher, 2016; Scholten & Schilder, 2015). Transparency, information sharing, and coordination are important areas to handle risk. To achieve this, involved parties have to be committed, build trust and collaborate (Christopher, 2016; Jain et al., 2017; C.-L. Liu & Lee, 2018). Successful cooperation throughout the whole chain, both upstream and downstream will increase the overall end-customer demands and could therefore strengthen service levels, reduce misunderstandings and by this enhance SC resilience (Christopher, 2016; C.-L. Liu & Lee, 2018).

Collaboration is strongly affected by visibility throughout the SC. Therefore, when experiencing disruptions like those in focus, SC visibility is another very important aspect to achieve SC resilience (Christopher, 2016). Complete visibility is sharing information from one end of the chain to another as close to real-time as possible and with the highest possible accuracy (Christopher, 2016). On the other side, limited visibility means that "a particular entity in the network is not aware of the status of upstream and downstream operations of the levels and flow of inventory as it progresses through the chain" (Christopher, 2016, p. 230). Trust and visibility are strongly correlated and a high degree of both can enable stronger relationships and collaboration between SC partners (Caridi et al., 2014). SC visibility throughout the whole chain could help to deal with issues and reduce the negative effects of disruptions.

In times of disruptions agile and flexible companies seems to be the most resilient (Gunessee & Subramanian, 2020), something substantiating the importance of flexibility concerning SCR. Flexibility extends from one end of the SC to the other

and is based on how organizations within the supply/demand network relate to each other and work together with shared information to reduce uncertainty (Christopher, 2016).

Velocity is a key aspect in the foundations for a responsive SC, which refers to responding more rapidly to SC changes, recovering and adapting consequently (Christopher, 2016; Jüttner & Maklan, 2011; Ponomarov & Holcomb, 2009). Based on this, velocity is a key competence for SC when confronting disruptions (Mandal et al., 2016). Further, Scholten & Schilder (2015) states that velocity provided sufficiently and the right information could reduce response and recovery times when facing issues.

3.5 Reliability

Thomas (2002) defines SC reliability as "the probability of the chain meeting mission requirements to provide the required supplies to the critical transfer points within the system". Moreover, an SC is considered reliable if it performs well even if one part of the chain fails (Miao et al., 2009). SCs being reliable is crucial for the economic growth and productivity of nations and the world (Goel et al., 2020). In SC reliability, delivery reliability, customer relationship and supplier relationship are the decisive factors (Bø et al., 2022).

Disruptions, causing bottlenecks, inefficient processes and fluctuations in the volume handled will increase variation in time taken for the activities within the order-to-delivery cycle to be completed (Christopher, 2016). In order, the effect of this could decrease the overall reliability of delivery, negatively affecting the SC performance. Reliable SCs are key to effectiveness and efficiency achievements, and therefore also SC performance (Wu & Barnes, 2018). Further, with stability and reliability, it is easier to effectively manage supply networks and build relationships (Adenso-Diaz et al., 2012). The key to building reliable relationships is the aspects of visibility and collaboration, which in order enhance trust and enables agility when unexpected changes such as disruptions occur (Hobbs, 2020). Relationships are of high importance for SCs reliability, and the buyer/supplier relationship should be based upon a partnership (Christopher, 2016). Partnership sourcing is widespread due to benefits such as improved quality, innovation

sharing, reduced cost, and integrated scheduling of production and deliveries (Ambrose et al., 2010; Christopher, 2016). Successful relationships within SCs will help the overall performance and increase the possibility of successful SCM in times of crisis (Ambrose et al., 2010; Christopher, 2016).

Experiencing disruptions such as COVID-19, the Suez Canal blockage and the War in Ukraine has increased the awareness and interest in the subject of reliable deliveries (Goel et al., 2020, 2021). Disruptions have affected the SCs, causing unreliably product delivery (Allegro Logistics, 2020). These disruptions affect companies in other industries as well as logistics companies, causing companies in a lot of different sectors to struggle without a constant and reliable container shipping industry (Allegro Logistics, 2020). The pandemic exposed concerns already trending in the industry, namely labour shortages and new infrastructure needs, causing an unreliable delivery (UNCTAD, 2021).

The elements of resilience such as long and trusting relationships across the chain can contribute to agility and cooperation, which enables reliability (Bø et al., 2022). This substantiates that some elements of resilience, are closely connected with reliability, and these aspects are therefore considered important and useful when it comes to SCRM.

3.6 Industry 4.0

Industry 4.0 or the fourth industrial revolution comprises the digitalization of the industrial sector with the use of the technologies robotics, Artificial Intelligence (AI), Internet of Things (IoT), blockchain, big data and 5G technology (Hahn, 2020). In industry 4.0 computers are connected through these advanced technologies which could communicate with one another to make decisions without human involvement (Dolgui & Ivanov, 2022; Frankenfield, 2020; Gillis, 2021; Hayes, 2022; Marr, 2018).

Globally interconnected SCs are dependent on cooperation and transparency, something technologies such as Blockchain, IoT and 5G facilitate (Czachorowski et al., 2019; Dolgui & Ivanov, 2022; Jones, 2020; Tapscott & Tapscott, 2018). At the same time, the technologies robotics, AI and Big Data enhance efficiency and

quality improvement of the operational capabilities in the global container shipping industry (Chu et al., 2018; DeChant, 2020; Love, 2020). Despite huge possibilities with the use of industry 4.0 technologies only some of the pillars are mature enough for the maritime industry, while others remain in their earliest stages in this business (de la Peña Zarzuelo et al., 2020). The technologies robotics, AI and Big Data are already commonly used in the industry, while Blockchain, IoT and 5G are in the early stage.

With the use of the aforementioned technologies the industry could enable people, machines, sensors, and devices to connect and communicate with each other (de la Peña Zarzuelo et al., 2020; Rao & Prasad, 2018). Further, the creation of systems through 5G and IoT, namely cyber-physical systems enables seamless and instant sharing of real-time data (de la Peña Zarzuelo et al., 2020; Rao & Prasad, 2018). These factors increase transparency, something that improves relationships between SC entities and enhances SC resilience and reliability. Automation is another important aspect of improved SC capabilities, where decision-making can be done without human interaction, and robotics and AI could increase overall efficiency in the container handling (Rao & Prasad, 2018).

Technologies central in industry 4.0 played a decisive role for many companies in response to pressure and issues following the scoped disruptions (Agrawal et al., 2021). COVID-19, the Suez Canal blockage and the War in Ukraine have highly influenced manufacturing, and SCs in an unprecedented way. Following this, McKinsey suggests three outcomes for companies: a win for those that had already scaled digital technologies, a reality check for those still scaling, and a wake-up call for those that hadn't started their industry 4.0 journeys (Agrawal et al., 2021). Despite companies already rethinking their global manufacturing and SC strategies, the mentioned disruptions could be a technological accelerator for the business world (Agrawal et al., 2021; Umbarkar et al., 2021).

The mentioned crises have made companies rethink their operational strategies and their direction going forward, changing both the business issue they want to address and the Industry 4.0 technologies they use to do so (Agrawal et al., 2021). Moreover, under the unique circumstances following the pandemic, the blockage and the war, strategic priorities are shifting from productivity and minimizing cost

to agility, flexibility, and manufacturing efficiency (Agrawal et al., 2021). Companies will always aim to be as productive and cost-efficient as possible, however, during disruptions this is not the main strategic focus.

The common denominator for companies surviving the pandemic has been fourth industrial revolution technologies, which emerged as key drivers of resilient SCs (Umbarkar et al., 2021). Worldwide and regional crises are believed to intensify in scale and frequency due to economic, social, and environmental changes (Umbarkar et al., 2021). Therefore, companies and industries investing in industry 4.0 technologies will be better equipped for dealing with new disruptions (Umbarkar et al., 2021).

Chapter 4 – Findings and analysis

This section of the paper presents the combination of theoretical findings and analysis of the data. Combining the most relevant findings will help to answer the research question: "*How have disruptions such as the COVID-19 pandemic, the Suez Canal blockage and the war of Ukraine influenced the container shipping industry, and how can the industry prepare for disruptions in the future*". A short introduction of the three disruptions is presented, before analyzing how they have influenced the container shipping industry.

4.1 COVID-19

The coronavirus was first found at a Chinese seafood and poultry market in December 2019, globally it has infected more than 540 million people. As of 12th of June 2022, it has caused the death of over 6 million people and over 515 million people have recovered from infection (*COVID Live - Coronavirus Statistics - Worldometer*, n.d.). To deal with the pandemic countries and governments introduced measures that globally affected people, companies, organizations and trade The coronavirus family includes different viruses that can cause respiratory infection (FHI, 2022). The different variants of the virus have strongly affected the severity and longevity of the pandemic since some of the mutations could escape the immune system even after vaccination or having had the disease. Further, the

mode of transmission, which is close contact with an infected person, is another factor influencing the extremity of the pandemic. While a person with influenza infects 1-2 other persons, a person infected with a coronavirus infects 2-3 others. These numbers, together with the fact that the incubation time is usually 4-5 days substantiate the issues with handling spreading the virus (FHI, 2022). Following this, it is safe to say that the COVID-19 pandemic has severely influenced the business world.

4.2 The Suez Canal blockage

On March 23, 2021, one of the world´s largest container ships, Ever Given, blocked the Suez Canal (Lee & Wong, 2021). The canal is located in Egypt and is an artificial trading waterway connecting the Mediterranean Sea to the Red Sea. Vessels were waiting more than 6 days to pass through the canal, until Ever Given on March 29, 2021, finally was freed (Lee & Wong, 2021). The Suez Canal is of huge importance for global trade, where approximately 30 percent of all global container traffic, representing 12 percent of global trade, passes through the canal (New Zealand Ministry of Foreign Affairs and Trade, 2021). In 2020 around 19 000 ships used the route, making it 52 ships per day going between the Suez Port and Port Said (New Zealand Ministry of Foreign Affairs and Trade, 2021). The container shipping industry, already significantly affected by the COVID-19 pandemic, took even greater damage after the Suez Canal blockage.

4.3 The War in Ukraine

This year, on February 24th, Russia invaded Ukraine and initiated a war. As a result of the war, the prices for oil and energy have increased significantly, strongly affecting the container shipping industry and the cost of transporting. The war also resulted in Russian forces shutting off shipping routes, and logistics companies suspending their services (Tan, 2022). Cargo movements are also standing still because the Ukrainian ports of Odessa and Mariupol are closed, damaged or under attack. Moreover, Russian and Ukrainian seafarers account for 14,5 percent of the global shipping workforce, and the International Chamber of Shipping warned that, because of the war, the SC disruptions are to be worsened by a shortfall in shipping crew (Tan, 2022).

4.4 Disruptions

Implications of disruptions for complex global SCs could occur in three fundamental ways, or as a combination of Supply shocks, distribution constraints and demand shocks (Notteboom et al., 2021). As illustrated in figure 5.

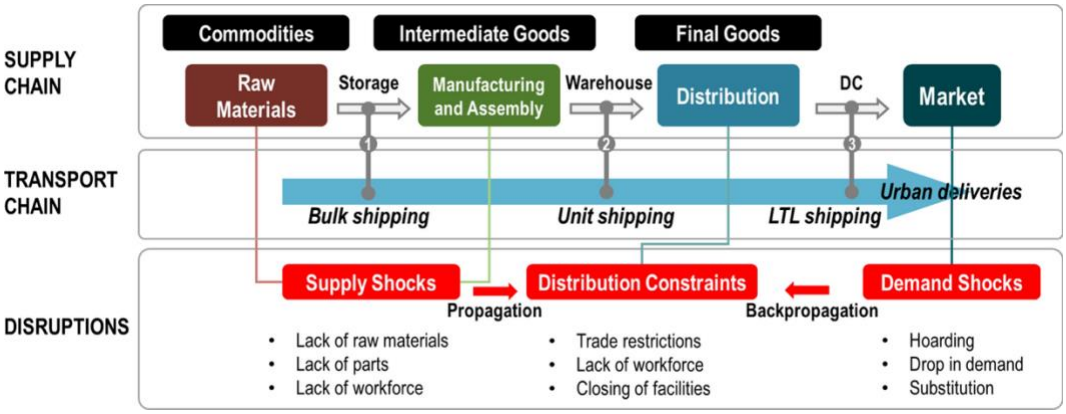

Figure 5: SC shocks caused by disruptions (Notteboom et al., 2021).

Supply shocks represent an unexpected sudden change in the availability of products, often caused by the lack of manufacturing capabilities affected by lack of raw materials, parts or workforce (Knowler, 2020; Notteboom et al., 2021). In the analysis of the mentioned disruptions, the lack of workforce is the most significant. Supply shocks are ultimately resulting in unforeseen price changes. Distribution constraints include trade restrictions, lack of workforce and closed facilities. The analysis reveals that the disruptions, especially COVID-19, have influenced the global SC and the container shipping industry substantially. Demand shocks are caused by a sudden change in demand due to unexpected circumstances (Notteboom et al., 2021; World Trade Organization, 2020). Hoarding, drop in demand and substitution can cause this sudden change in demand. At the beginning of the pandemic, people were stocking up on products like toilet paper. There was no direct drop in demand, but rather a change. Restrictions to prevent the spread of COVID-19 were forcing people to stay inside, and restaurants and other services to close, resulting in the consumer demand to change. Consumers substituted consumption patterns, focusing on essential goods, such as food and home goods, instead of restaurants and social activities (Notteboom et al., 2021). Following a disruption, several concurrent shocks in SCs are caused by the coevolution of

propagation and backpropagation mechanisms (Notteboom et al., 2021), something causing disruptions all over the chain and severely influencing the world.

4.5 Increased demand

Container demand is driven by end consumer spending on goods, and COVID-19 led to a boom in demand for containerized consumer goods in the US, reducing effective container logistics capacity, and causing congestions (Dierker et al., 2022). People stayed more at home, resulting in changes in consumers purchasing behaviours (Dierker et al., 2022). Consumers' spending shifted from services to goods due to restrictions imposed by national lockdowns (Youd, 2021). Working from home, less travel and lockdowns resulted in people investing in new furniture, electronics, and sports equipment (Wrede, 2021). North America saw import volumes of products jump an average of approximately 20 percent throughout 2021, compared to 2019 (Dierker et al., 2022). Moreover, COVID-19 shifted the share of US personal spending on goods from 31 percent to 35 percent, and between September 2019 and September 2021, the spending on goods was 14 percent higher than before the pandemic. The graph below (figure 6) shows how consumer spending on goods in the US first dropped significantly in March 2020, when the pandemic hit the world before it increased considerably in the following months.

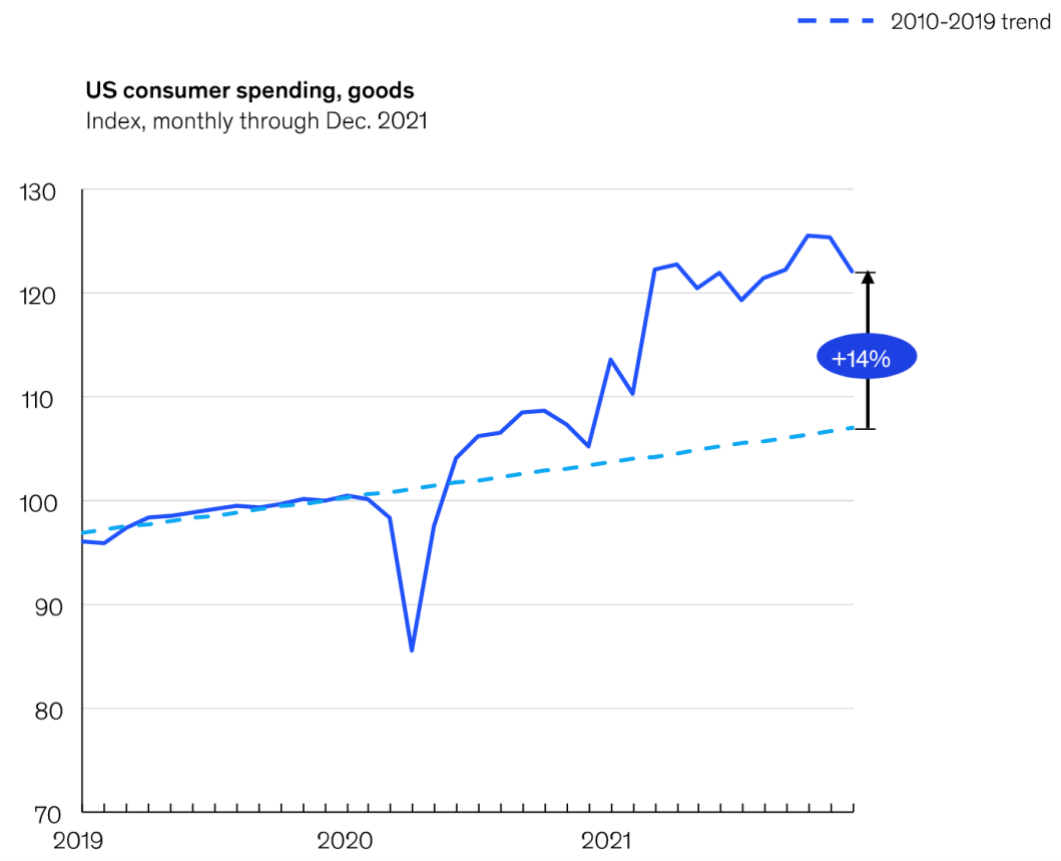

Figure 6: Increased spending on goods (Dierker et al., 2022).

The next graph (figure 7) shows how consumer spending in the US after COVID-19 was way below the average trend between 2010 – 2019. Together with the above graph, this shows how peoples spending shifted from services to goods during the pandemic.

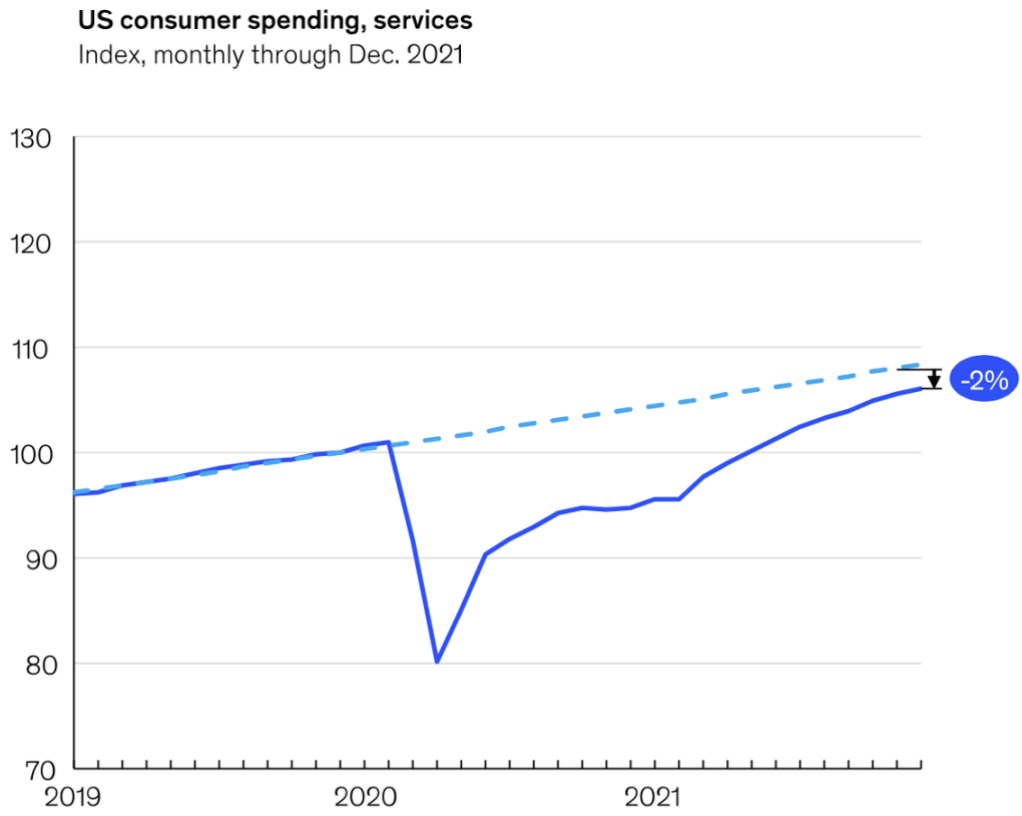

Figure 7: Decrease spending on services (Dierker et al., 2022).

Consequently, fleets were not able to grow fast enough to keep up with the increased demand for goods and container shipping (Wrede, 2021). Nils Haupt from Hapag Lloyd´s stated that it is impossible to charter ships: "All ships that can carry containers and that are not in shipyards for repairs are in use, and there are no spare containers", also confirmed by Ralf Nagel from the German Shipowners Association (Wrede, 2021).

4.6 Closed borders and ports

When the COVID-19 pandemic hit, countries and governments began the implementation of national lockdowns and ceased the production of goods, ultimately pulling the plug on economic growth (Youd, 2021). Ships were also quarantined as a measure to continue the fight against COVID-19, and port authorities around the world maintained strict protocols trying to prevent the spread of the virus (The Maritime Executive, 2020). Consequently, ports all around the world struggled to manage their operations during the pandemic (The Maritime Executive, 2020).

Authorities shut down districts and businesses to prevent the virus from spreading rapidly, causing massive delays and jacking up the shipping costs (Tan, 2021b). In Los Angeles for instance, ships had to wait about 10 days before being allowed to enter the ports as a result of the lack of staff (Wrede, 2021). Lockdown measures, sick leaves and sometimes isolating whole crews in quarantines reduced the availability of staff at ports. Moreover, containers tended to be at sea much longer than usual due to delays at ports, on canals, and during inland transportation (Wrede, 2021). Hapag Lloyds ships were on average 170 hours late on their most frequent routes, and on trans-pacific routes, the delay added up to 250 hours on average (Wrede, 2021). With the Suez Canal blockage, the delays increased additionally.

Figure 8 shows average monthly delays for late container vessel arrivals worldwide from 2019 until 2022 and is substantiating the above findings. The virus was first detected in late 2019 in China. From the number of delays in figure 8, we can see an increase from December until February 2020, before it decreases. In late February/ early March 2020, when the virus became global and countries initiated lockdowns and closed borders, the average delays increased again until June 2020. On July 10, 2020, the U.S set seven records in 11 days and reached 68,000 new cases of infection for the first time (Taylor, 2021). In addition, Hong Kong shut down schools on the same date, to prevent a third wave of infections. On August 1, 2020, the US saw July cases more than double the total of any other month and recorded more than 1.9 million new infections. The previous monthly high was in April when more than 800,000 new cases were recorded (Taylor, 2021). In figure 8 you can see how the delays increased significantly from August 1st, strongly correlated with the high increase of new cases detected in July. Delays increased continuously until February 2021, before they dropped. The decrease continued until late March 2021, when the Suez Canal blockage occurred. The graph shows how the blockage influenced the industry significantly and increased the delays for container vessels even more. Additionally, the delta version of the virus started to dominate in May 2021. As a consequence of these two factors, the average delays rise to the highest number since the outbreak of the virus, substantiating that the disruptions together influence the industry in a serious matter. In addition to the two disruptions mentioned above, the War in Ukraine started in late February 2022.

Without having numbers proving the impact of the War in Ukraine on container delays, the war is likely to have caused even further delays and disruptions.

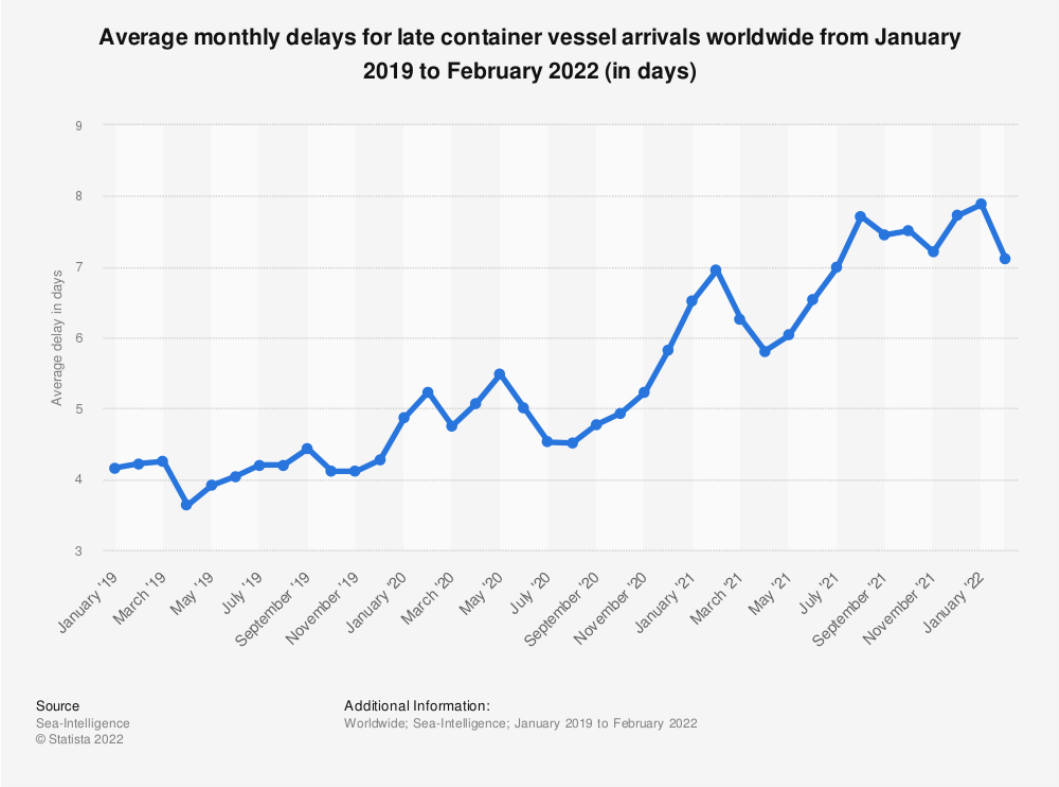

Figure 8: Monthly delays container vessels (Statista, 2022).

The number of average delays of container vessels is highly influenced by disruptions such as COVID-19, the Suez Canal blockage and the War in Ukraine. SC reliability and resilience were tested during these different events. When it comes to reliability, an SC is considered reliable if it performs well even if one part of the chain fails (Miao et al., 2009). Based on the average number of delays correlating with the different effects of the coronavirus and the Suez Canal blockage, it can be argued that container shipping is unreliable. SCs are resilient if they can respond and bounce back after disruptions (Ponomarov & Holcomb, 2009). Average delays of container vessels decreased after the main events mentioned above but were at the same time higher than before the events. Therefore, it could be argued that the industry to a certain extent is resilient. On the other hand, average delays never returned to the original state after being disturbed. Since resilience also is considered the ability of a system to return to its original or desired state after being disturbed (Christopher, 2016, p. 232), the resilience in the industry was not good enough to deal with the disruptions.

In the fourth busiest container port in the world, Port of Yantian, satellite images showed a backlog of containers awaiting export after the Covid outbreak (LaRocco, 2021). According to logistics companies with operating knowledge of the port, approximately 300.000 TEUs were waiting to be exported (LaRocco, 2021). TEU stands for a Twenty-foot-Equivalent unit and is defined as a shipping container with internal dimensions measuring 20-feet long, 8-feet wide, and 8-feet tall (Pappas, 2011). The waiting time for vessels to berth at the Yantian container terminal increased from 0.5 days to 16 days during the pandemic (Tan, 2021b). Backlogs, caused by closed borders and ports, and disrupted by the delays following the different stages of the coronavirus pandemic decreased the reliability of the industry.

Substantiating the effects on the industry caused by closed borders and ports, the graph below shows container fleet capacity lost due to congestion and delays from 2019 to 2022. Loss in global container fleet capacity increased from December 2019 to January 2020, most likely correlated with lockdowns in Asia because of the outbreak of the COVID-19. On July 1st, 2021 the share of global container fleet capacity lost due to port congestions and vessel delays increased significantly. Strongly connected to major growth in new cases of COVID-19. The increase continues to February 2021, before it decreases. In April 2021, right after the Suez Canal blockage occurred, the graph begins to increase again. The effect of the blockage on container fleet capacity and delays was additionally boosted by the detection of the Delta variant of the virus in late May 2021.

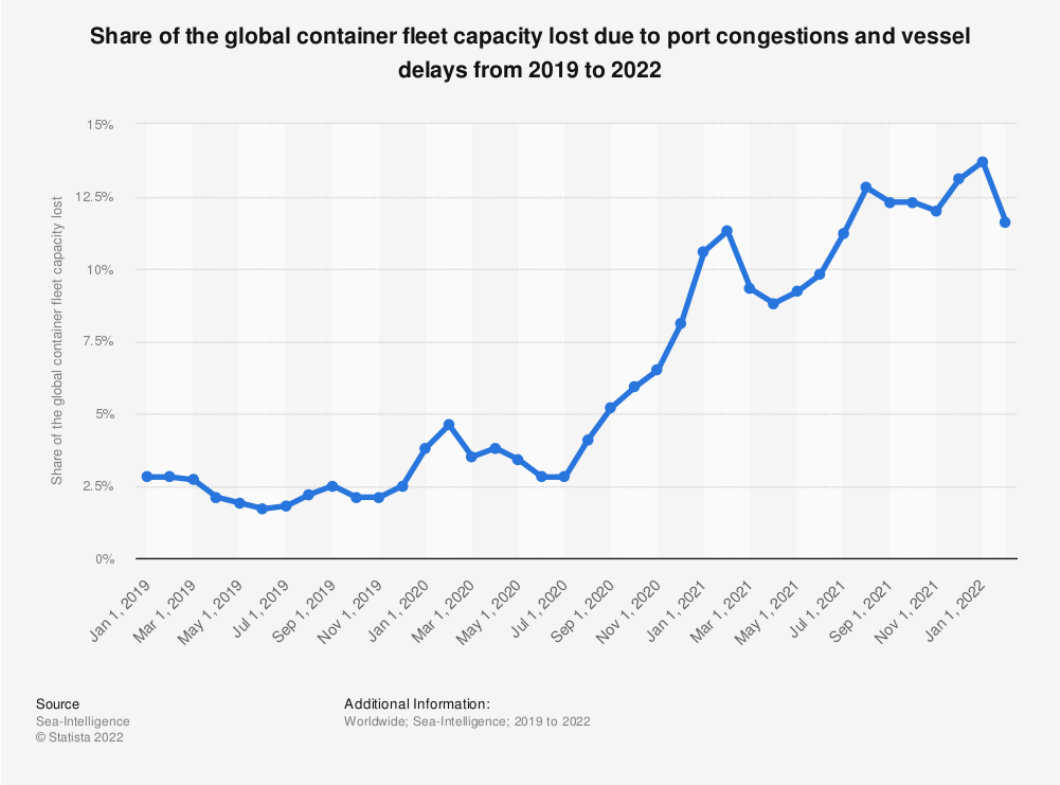

Figure 9: Container fleet capacity loss (Statista, 2022).

Since the outbreak of COVID-19 the container shipping industry has been under serious pressure, testing the resilience and reliability of the industry. With government restrictions in different countries at different times, chronologically following the different waves of the pandemic both capacity loss of the container fleet and delays of arrival have increased significantly. These effects have been enlarged by the Suez Canal blockage.

4.7 Lack of drivers

Trucking is one of the most critical parts of the modern SC where it enables the last mile journey of all products (Mittal et al., 2018). With the growth in e-commerce, the demand for truck drivers has grown exponentially, however, the trucking industry is not able to meet the increasing demand because of a severe shortage of truck drivers (Mittal et al., 2018). The driver shortage is a longstanding issue for the trucking industry and has been discussed in research for years. The American Trucking Association estimates that nearly 33 percent of the shortages are caused by the increase in trade demand (American Trucking Association 2015a, pp. 1–13, cited in (Mittal et al., 2018).

Moreover, the American Trucking Association stated that due to retirements and people leaving the industry, trucking companies need to recruit nearly 100,000 new drivers yearly over a decade to keep up with the growing freight need in the US (American Trucking Association, 2016a), cited in (Mittal et al., 2018).
Figure 10 below shows a prediction of how much the truck driver shortage in the US will increase over the next few years.

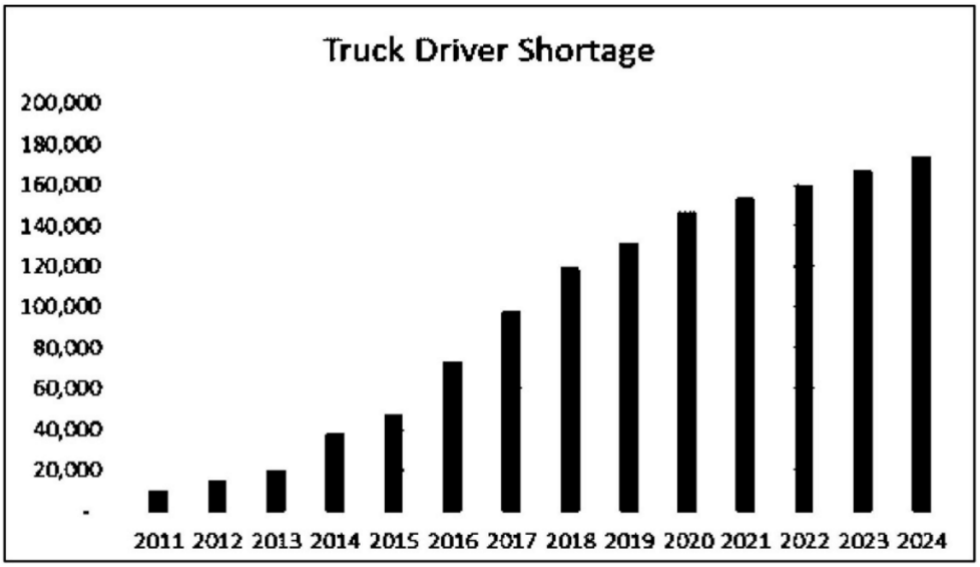

Figure 10: Truck driver shortage (American Trucking Associations, 2021).

Moving forward, the American Trucking Associations' predictions were not completely true, however, the increase has still been significant. A new update estimates that in 2021 the truck driver shortage will hit a historic high of just over 80,000 drivers (American Trucking Associations, 2021) New predictions have been made, and the figure 11 below shows the estimated truck driver shortages from 2020 to 2030, where they estimate the shortage to surpass 160,000 (American Trucking Associations, 2021).

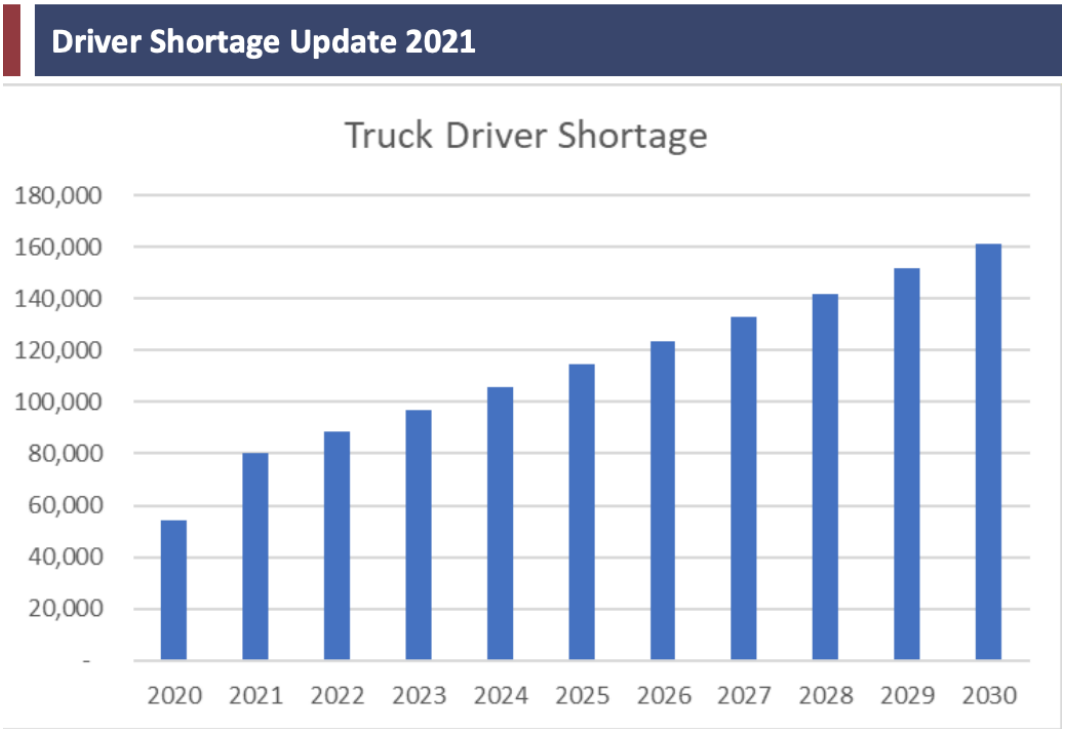

Figure 11: Updated truck driver shortage (American Trucking Associations, 2021).

There is no single cause for the driver shortage, but some of the primary factors include the high average age of current drivers, the low percentage of women among the drivers, problems related to passing a drug test as drivers cross borders where states have legalized marijuana and others have banned it and a federal mandate to be minimum 21 to drive commercially across states (American Trucking Associations, 2021) The figure 11 shows the reasons for the estimated need for truck drivers presented above. Retirements are a large portion of this, which is related to the first point mentioned above. Moreover, drivers being pushed out of the industry and drivers leaving before retirement is a huge factor, strongly related to the working conditions. It is a job full of stress, physical deprivation, and loneliness, and people argue that the working condition is the fundamental reason for the truck driver shortages (Goodman, 2022).

The trucker shortage is not only a problem in the US. In Europe, soaring demands, low wages, and poor working conditions are causing a dearth of drivers (Vladkov & Arnold, 2021). The shortage of drivers is widespread across Europe, reaching 80,000 in Germany and 400,000 across the whole EU (Vladkov & Arnold, 2021). In the UK, the number of truck drivers dropped by 29,900 or 9,5 percent between March 2020 and March 2021, where more than half of the drop was due to Brexit

and EU citizens no longer being able to work as drivers in the UK (Vladkov & Arnold, 2021).

The paper reveals that there already was trouble keeping up with the demand due to a lack of drivers before the pandemic, then the COVID-19 pandemic hit, and increased the demand significantly leading to even less capacity (Delong, 2021). COVID-19 resulted in logistical challenges in many sectors, including the trucking industry. Truck drivers are essential workers who could not work remotely during the pandemic (Blau et al., 2021). Physical distancing measures, such as keeping a two-meter distance between people and quarantine requirements, resulted in an increased lack of drivers. Truck drivers are a critical workforce for moving shipments from one point to another. Marked interruptions, including events like the pandemic, can create massive shipping backlogs by clogging the ports (Delong, 2021). Hence, when carriers rush to catch up, the demand for truck drivers increases even further (Delong, 2021).

4.8 Container shortages

The pandemic caused a dramatic disturbance in the shipping industry when it came to container availability. It left companies unable to ship their products and resulted in a backlog of empty containers (Youd, 2021). At the beginning of the pandemic, companies started to reduce the number of cargo ships that were being sent out because of the national lockdowns and ceasing of production goods (Youd, 2021). This resulted in the usual flow of imported and exported goods stopping and empty containers not being collected. One of the most significant examples of this was that Asian containers shipped to the US could not be sent back due to COVID-19 restrictions in Asia (Youd, 2021). As different parts of the world bounced back from the pandemic at the end of 2020, the increased shipping demand led to the availability of containers falling critically low (Tan, 2021b). This further resulted in congestion of ships and/or containers in ports and affected the surrounding hinterland infrastructure (Remes & Saxon, 2021). The containers found themselves in inland depots and were stacking up at cargo ports (Youd, 2021).

Furthermore, a trade surplus further increased the container imbalance. China has more export to the US and Europe compared to their import. In addition, China's

economy bounced back faster and its borders were under control already in the second quarter of 2020 (Tan, 2021a). As Asia began to recover, the rest of the world was still facing national restrictions and containers could not be sent back to Asia (Youd, 2021). Consequently, containers were stuck in the west when needed in Asia. Figure 12 shows the largest container ports worldwide in 2021 based on the throughput of TEU containers.

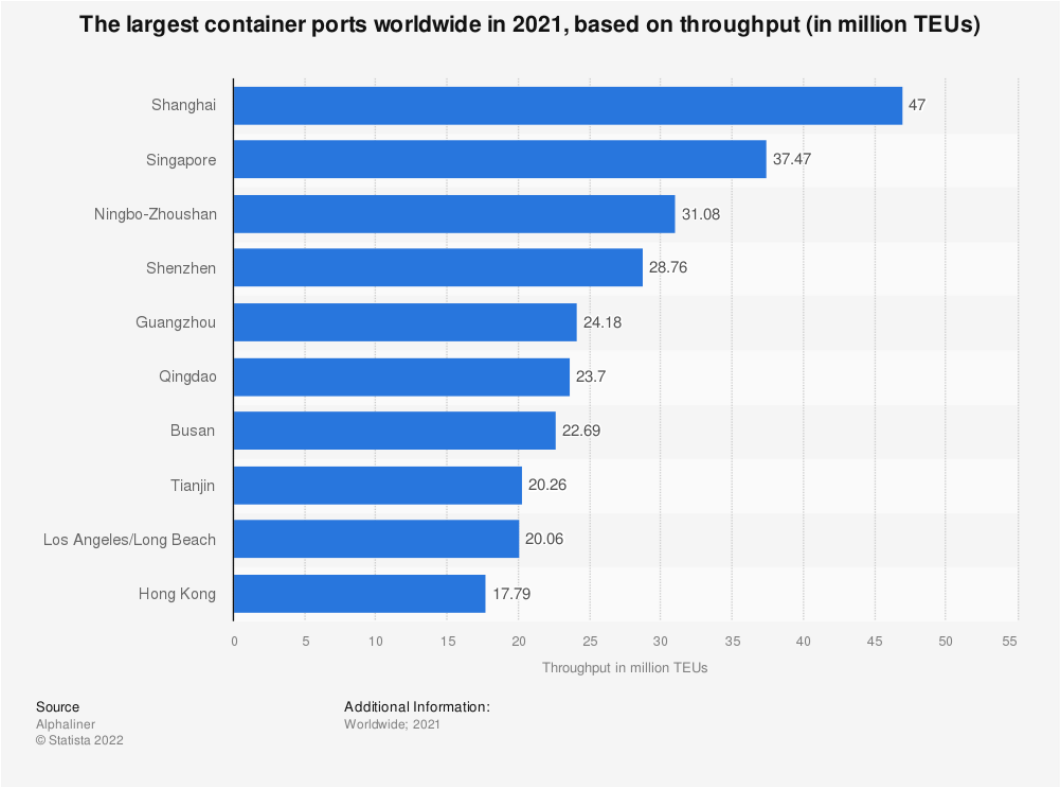

Figure 12: Largest container ports worldwide (Statista, 2022).

The experienced shortages of containers, especially in Asia proved to be a huge issue for the global container shipping industry. Because 9 of the 10 biggest ports based on throughput are based in Asia, the impact of shortages of containers was toughest in these regions, however impacting the global industry. Fewer available containers instigate harder competition for container space, leading to decreased reliability in the industry.

Even though containers were most needed in Asia because of their high export to the rest of the world, the shortage also impacted shipping from other parts of the world. In the UK for instance, the CEO of Hexstone group, Ian Doherty said that they had goods they wanted to ship, but was unable because of the lacking

availability of containers (Youd, 2021). Furthermore, Doherty expressed that the congestion at the ports led some cargo ships to drop their containers at other ports to avoid further delays – typically adding two weeks to the lead times, and laying further pressure on the container availability (Youd, 2021). International flight volumes also plunged due to COVID-19 travel restrictions. As a result, high-value items such as iPhones were transported by containerships, and the shortage was further exacerbated by this limitation of air freight capacity (Tan, 2021a).

4.9 Increased prices

Shipping rates are a major component of trade costs and container rates have a particular impact on global trade since all manufactured goods, including clothes, medicines, and processed food products are shipped in containers. (Unctad, 2021). Usually in a dynamic market with free competition supply and demand interact dynamically and will eventually culminate in an equilibrium of prices. However, the theory assumes that there is a gap between the actual price and the equilibrium price, EQ (Munichiello, 2021). The equilibrium price is a balance between demand and supply factors. After disruptions which influence the prices, it is a tendency for prices to return to equilibrium unless some characteristics of demand and/or supply change. Following the influence of the disruptions investigated in this thesis, prices changed severely. The long-term influence on prices is still to be found out. Further in this section the authors will discuss and highlight the price changes with the use of macroeconomic theory and different scenarios of the disruptions of scope.

Figure 13 shows how demand and supply interact, creating the state of the equilibrium price. In a container shipping setting, this will be the predicted market price or freight rates in a normal situation without external influence (Khan Academy, n.d.). Moreover, in figure 13 below you can see how the supply curve and the demand curve interact in a graph and determine the price and the quantity that will be bought and sold in the market – marked as EQ. Before the COVID-19 pandemic hit the container shipping industry was in this equilibrium state. Understanding the economic aspects of the industry is important to understand how severe the influence of the disruptions has been on the freight rates. In an equilibrium state, the actors in the industry operate with margins and uncertainty regarding demand, supply and prices are low. However, when something happens

that influences these aspects, every entity in the industry is affected in one way or another, this is investigated further in this section.

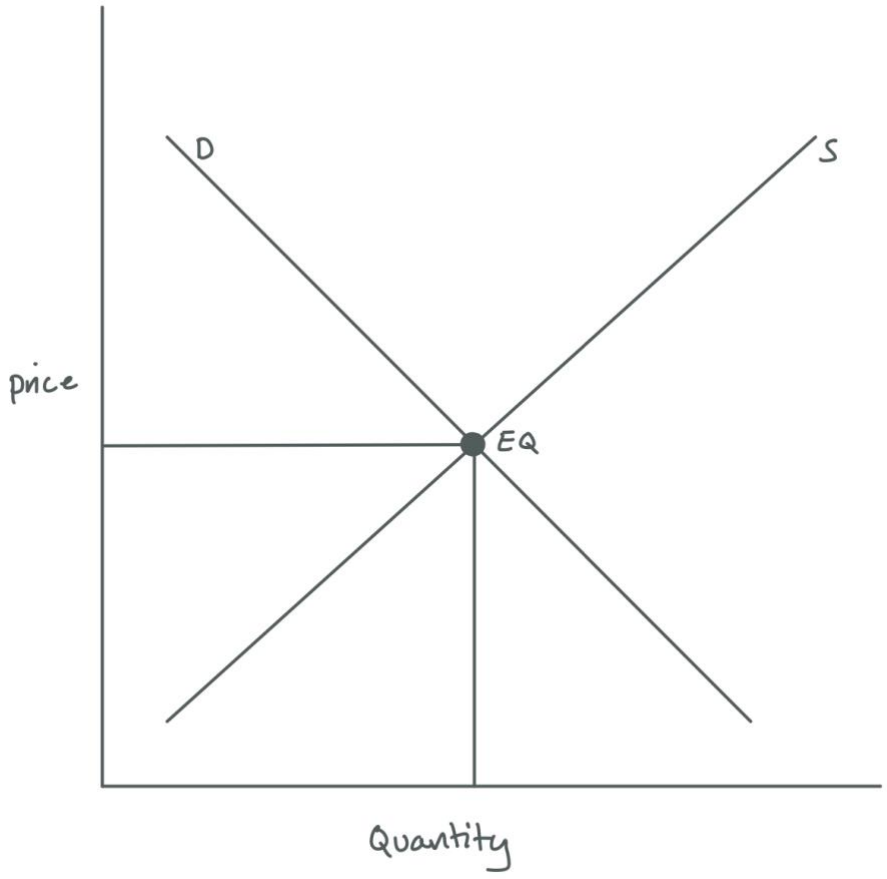

Figure 13: Equilibrium price

While figure 13 shows the EQ in a dynamic market, which the container shipping industry was in before the pandemic hit, it is safe to say that the state has changed significantly since the outbreak of COVID-19. High demand and container shortages have resulted in soaring cargo rates. According to Nils Haup from Hapag Lloyd, cargo rates were up to four times higher at the beginning of 2021 compared to the year before (Wrede, 2021). Companies got desperate, waited weeks for containers and paid premium rates to get them, resulting in container freight rates increasing (Tan, 2021a). The rates continued to increase, and in August 2021, it costed up to six times more to ship a container compared to the beginning of 2019 (Remes & Saxon, 2021). Figure 14 substantiates these findings and is also correlated to the different waves of the pandemic. Figure 14 also shows a strong correlation between the Suez Canal blockage and freight rates. Figure 14 shows that

rates started to increase significantly after the Suez Canal blockage and at the same time the spreading of the delta variant. Container freight rates reached a global maximum in September 2021, something that disputably did relate to the pandemic and Suez Canal blockage.

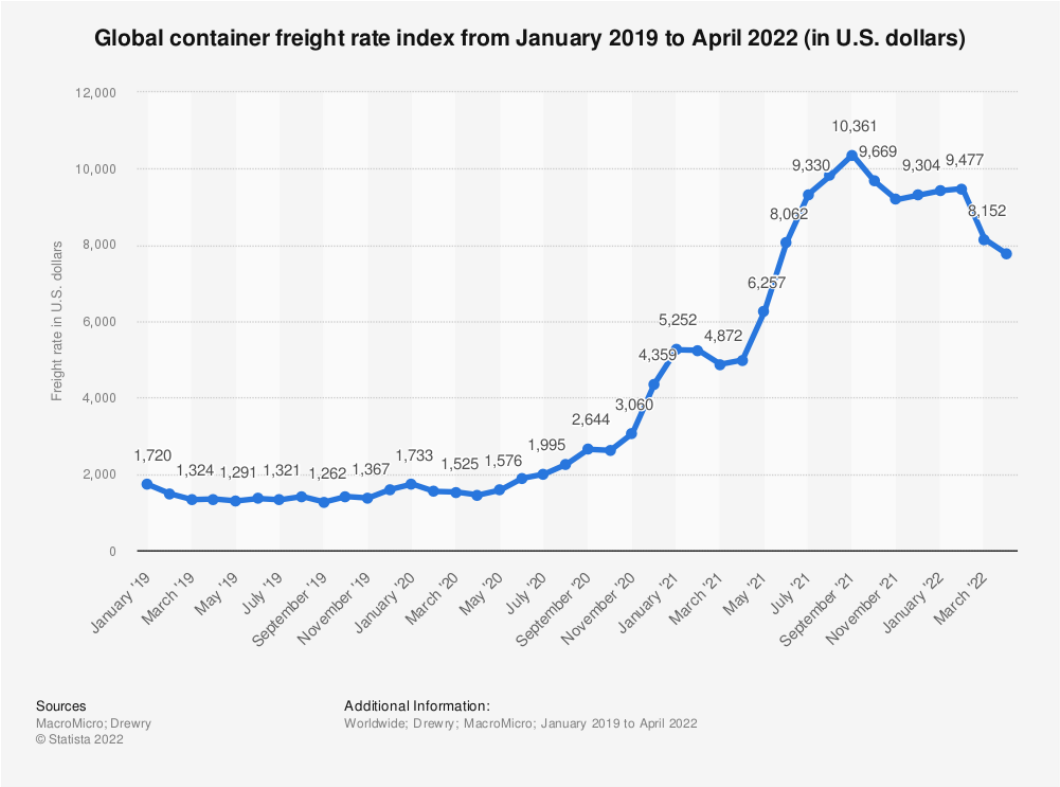

Figure 14: Container freight rate index (Statista, 2022).

The knowledgeable effects of changing demand and shortages of containers could be discussed from a macroeconomic perspective. With the pandemic being a real-life situation with a shortage of and increased demand for containers, the situation increased the shipping costs on overseas ships, and at the same time created delays in the SCs. Supply, due to delays and shortages not being able to handle demand provoked the need for a new equilibrium state in the industry. Figure 15 shows how the situation changed from the equilibrium price before the outbreak of COVID-19 to a new equilibrium price in the market after the pandemic, the Suez Canal blockage and the War in Ukraine. With the increased demand for container space due to the external shocks, the prices increased and became the basis for a new equilibrium state (figure 15).

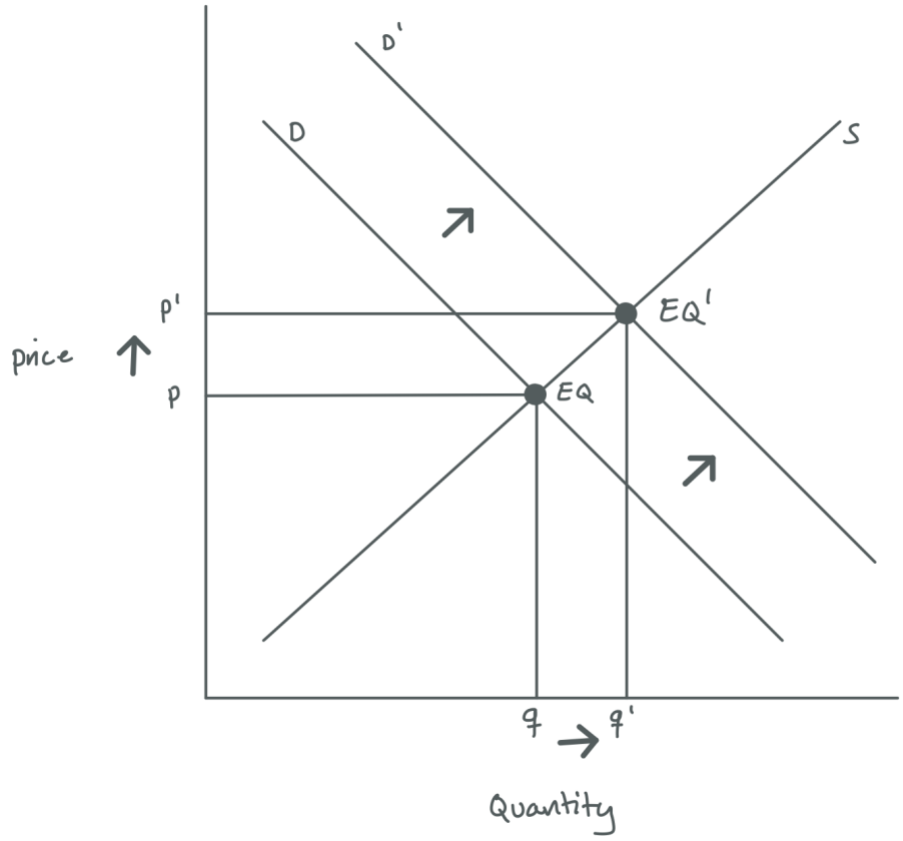

Figure 15: Demand increase equilibrium price

While figure 15 shows the price effects of demand increase, figure 16 shows another macroeconomic situation: namely a situation with supply decrease or shortages. Container shortages were especially a problem in Asia since they export more than they import. This leads to a trade surplus which is strictly dependent on the empty containers that got stuck on ships, container terminals and inland depots during COVID-19 and the Suez Canal blockage (Youd, 2021). Experiencing a demand increase, and at the same time a supply decrease with shortages of containers the market state changes again. Figure 16 addresses a situation with shortages of containers and a decrease in the supply of containers during the discussed disruptions. The new equilibrium state, with a price increase for container freight rates, is strongly influenced by this factor as well. As analyzed, the freight rates increased since the outbreak of the COVID-19 pandemic, and, likely, it is strongly correlated with the aspect of shortages as well as demand increase.

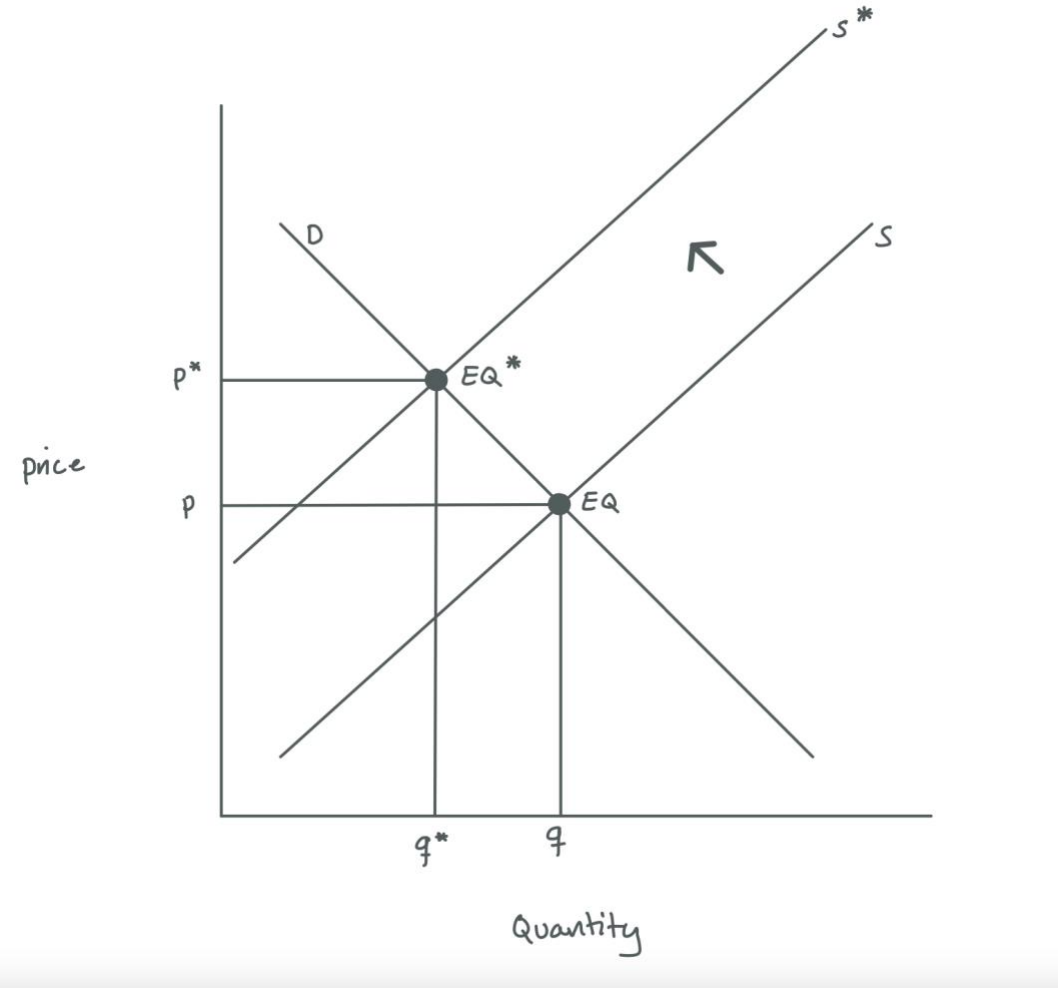

Figure 16: Shortages equilibrium price

Figure 16 above substantiates what theory states about shortages; namely that experiencing shortages of a good, in this case, a shortage of containers will increase the prices of the good (Pettinger, 2019). Shortages of goods and an increase in demand affect the price of the goods, increasing it. Furthermore, there are a few potential outcomes when the economy experiences shortages of a product or good. Pettinger (2019) mentions the following outcomes; waiting lists, increased demand for a substitute, making use of income, black market, and deadweight welfare loss. Since the outcomes of queueing (waiting list), substitute goods, or black market are very unlikely to happen considering the industry, the most likely outcome will be companies making use of income to buy container space.

Higher prices for containers influence the different entities in an SC in quite different ways. Company's willingness to pay for container space increased during the disruptions due to shortages and demand changes. Consequently, these companies will experience lower profitability than before the disruptions if they

keep the product prices at the same level. If they on the other side increase their product prices, end-consumers purchasing power decreases. Hence, the only party gaining from increased prices are the companies shipping the goods. Figure 17 shows the average earnings before interest and taxes (EBIT) margins of main container carriers from 2014 to 2021 and illustrates this. Since the outbreak of the virus, the average EBIT has increased significantly and is strongly correlated with the increased prices for containers. In a market strongly influenced by external factors such as the disruptions in scope, some entities will benefit, and others will draw disadvantages because of this. While companies carrying the containers overseas have increased their profits due to higher prices and low availability of containers, companies paying the freight rates find themselves in a quite opposite situation. Suffering from both higher prices and difficulties in getting hold of products both retailers and end-consumers suffered. Despite this, the business world is dependent on container shipping and the products being delivered by overseas cargo. Therefore, companies couldn't make use of other delivery alternatives, such as flights and trains, causing prices to not normalize. The Suez Canal blockage and the War in Ukraine are other factors strongly influencing the normalization of the freight rates and have also made the situation with high prices even more severe.

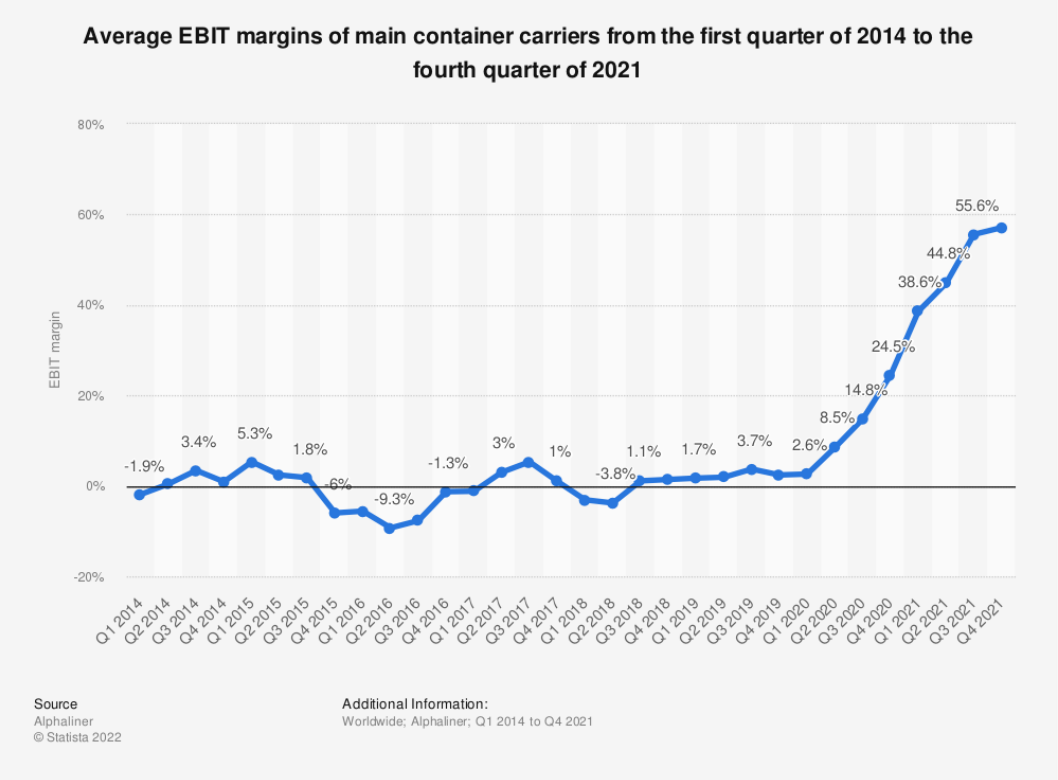

Figure 17: EBIT margins of main container carriers (Statista, 2022).

The big question now is how container freight rates will develop. The impact of the pandemic and blockage has been severe, forcing all entities within SC to question if the prices will normalize or not. A global survey about freight rates was conducted in 2021. The answers presented in figure 18 show that trade and logistics industry professionals believe that the prices will not normalize before late 2022 or during 2023. The survey also showed that as much as around 15 percent of the participants believe that prices will remain higher than before the outbreak of the pandemic.

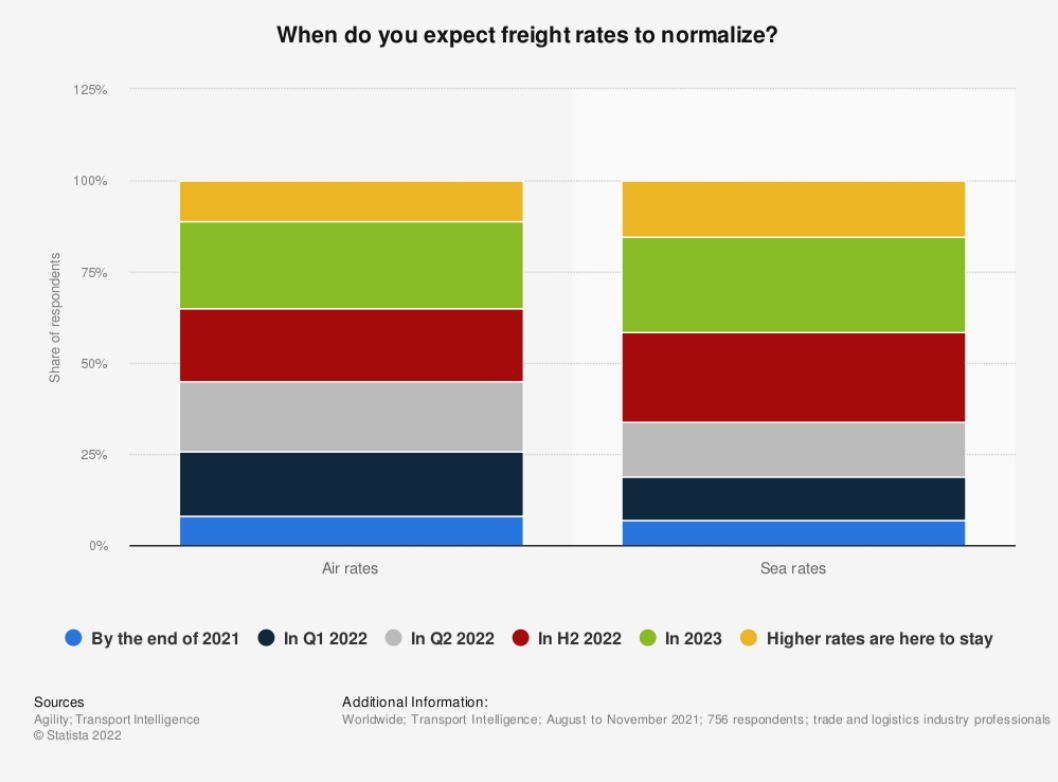

Figure 18: Normal freight rates (Statista, 2022).

Looking at this from a macroeconomic perspective, the effects of shortages and demand changes for containers could lead to an increased equilibrium for container freight rates. Price increases starting after the outbreak of COVID-19, and then the Suez Canal blockage, as well as the War in Ukraine, hit a market that was already under severe pressure making the impact even greater. While not one of the disruptions was foreseen, or the industry was prepared for it, the prices increased significantly with three such huge disruptions happening within 3 years. Therefore, the market would most likely operate with a new equilibrium price going forward.

Or at least the prices will not normalize before the War in Ukraine and the disruptions followed by that crisis are known and handled satisfactorily. In figure 19 the effects of the different disruptions on container prices are summarized, trying to show the new possibly equilibrium market price in response to the disruptions and the problems that followed. On the other side, with the War in Ukraine being a relatively new event the impact on prices and the container shipping industry, in general, are still unknown.

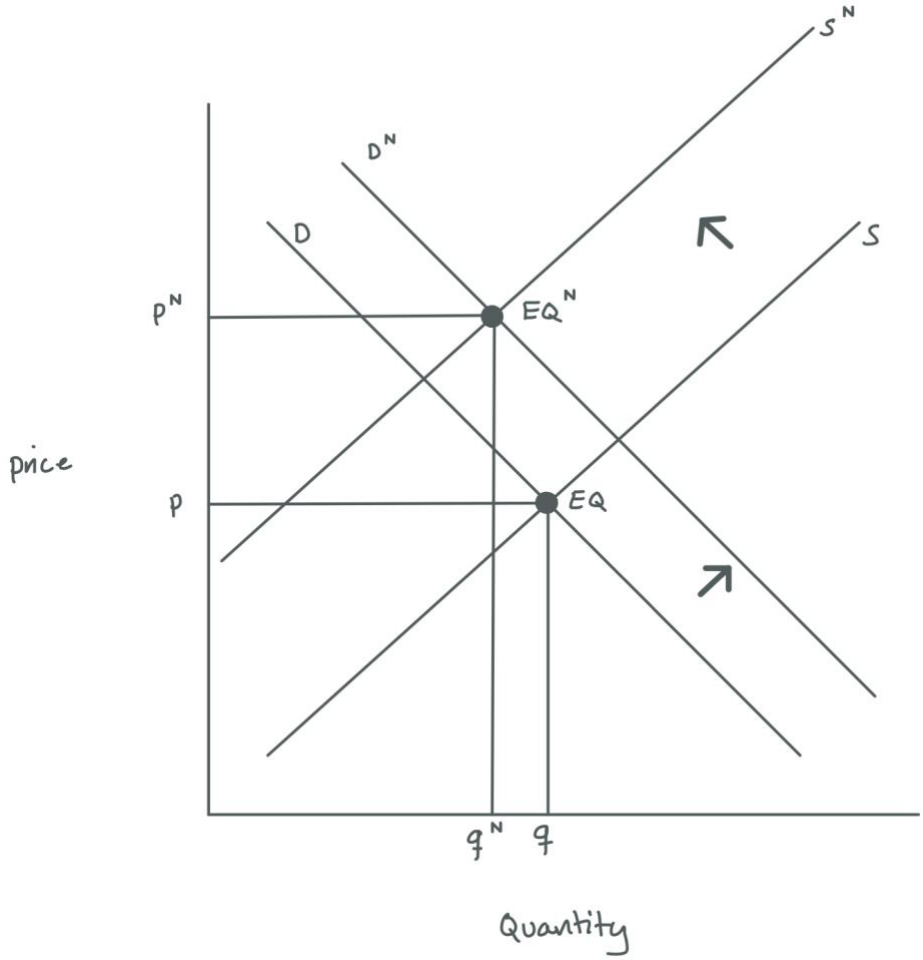

Figure 19: New equilibrium price

4.10 Reliability

The reliability of the container shipping industry has since the outbreak of COVID-19 decreased, causing problems with deliveries of products to companies and end consumers. With the importance of the container shipping industry, low reliability in the industry highly affects the economic performance in the business world as

well. Figure 20 shows the average monthly schedule reliability of main container carriers from the beginning of the pandemic until February 2022.

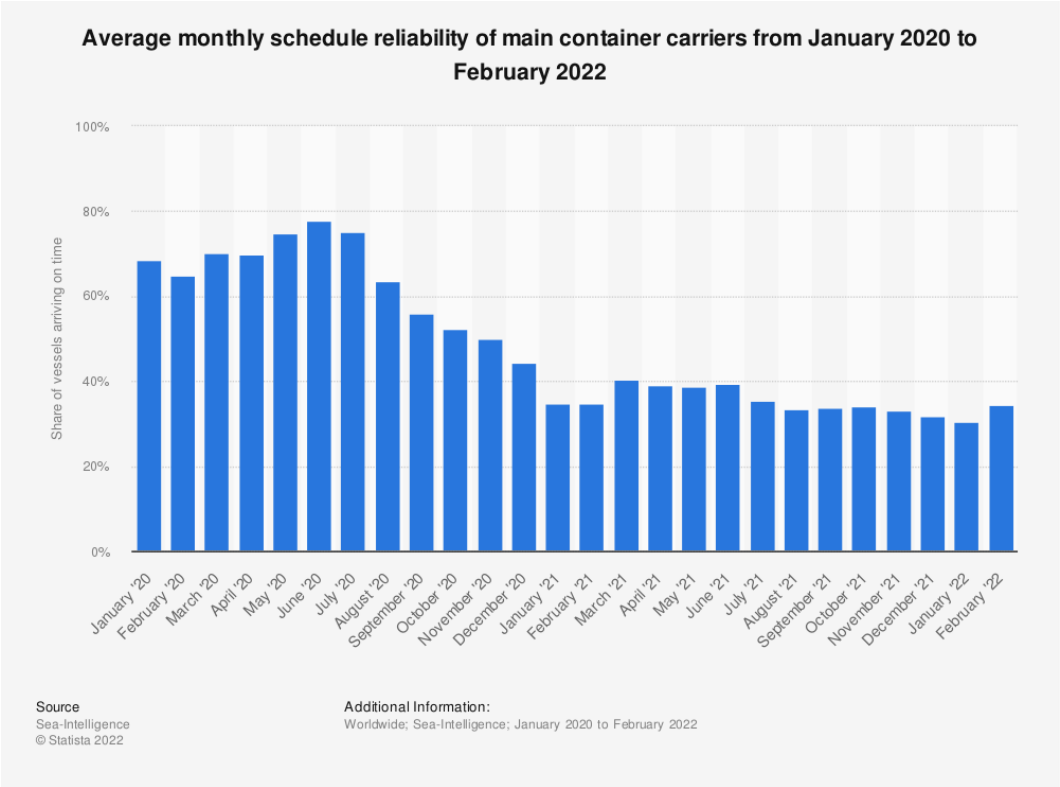

Figure 20: Monthly scheduled reliability (Statista, 2022).

Figure 20 clearly shows how reliability, decreased since the pandemic started, and how it was affected by the Suez Canal blockage. Reliability in April 2021 was not as low as expected after the blockage of the Suez Canal. However, since the outbreak of COVID-19, schedule reliability has been halved and is considered a severe change and problem for the industry. Figure 21 shows the average quarterly schedule reliability of main container carriers before and early pandemic. This figure substantiates the findings of the decrease in reliability in the container shipping industry.

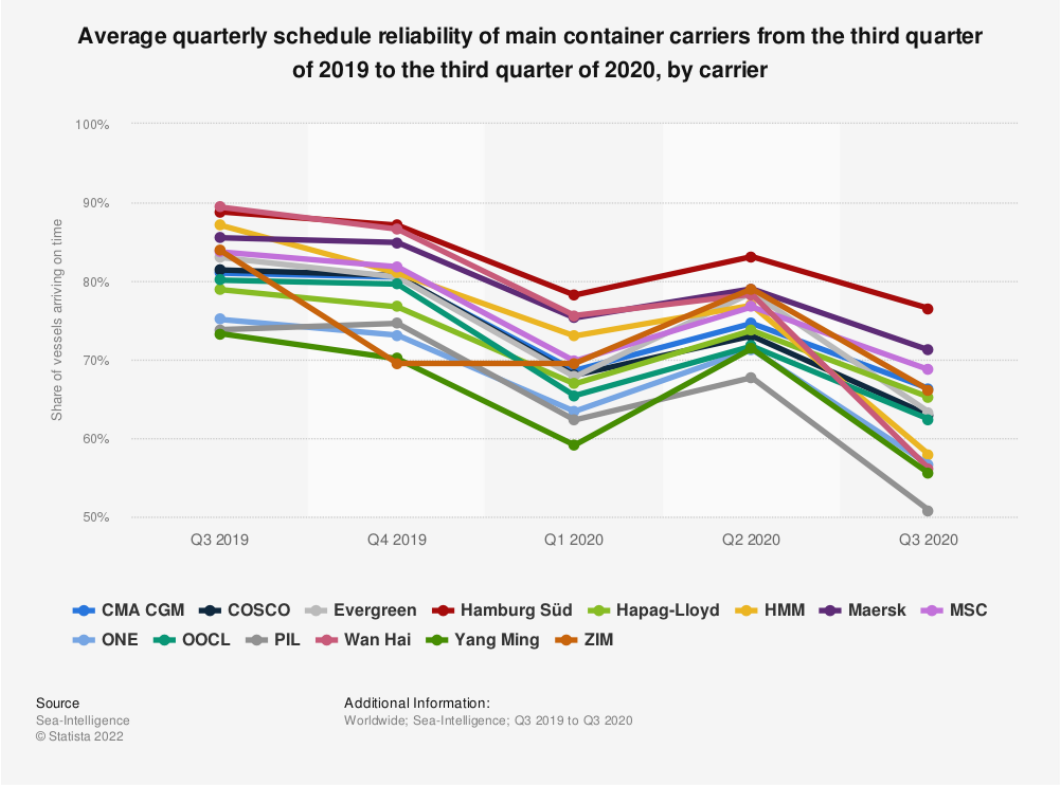

Figure 21: Quarterly scheduled reliability (Statista, 2022).

As figure 21 shows, the decrease in reliability from main container carriers since the outbreak of COVID-19 has been huge. With low reliability in the industry, companies' portfolio decreases, and end-consumers suffer from both fewer products available and the prices increasing. Low reliability in the industry with increased variation in the time it takes to finish activities within the order-to-delivery cycle negatively affected the SC performance during the disruptions. Strong relationships between SC partners are highlighted as one important factor for ensuring reliability within SCs (Hobbs, 2020).

Our findings could indicate that the relationships between entities in the container shipping industry are not as strong as they ought to be. Furthermore, we know that visibility and collaboration are important aspects to build strong relationships (Hobbs, 2020). Following this, our analysis and findings of reliability in the container shipping industry since the outbreak of COVID-19 indicate that the visibility and collaboration between industry partners are not good enough. Good relationships, with high visibility and collaboration, also enhance trust and enables the agility to deal with unexpected changes (Hobbs, 2020). Our analysis of reliability and the earlier analysis of delays and capacity lost to congestions since

the outbreak of COVID-19 substantiates that trust and agility in the industry are low. Altogether, our findings and analysis of reliability show that the industry could improve relationships between entities to improve the overall SC performance.

4.11 Resilience

In response to disruptions experiencing low reliability, resilience, and increased prices, companies all over the world have started reconsidering their business strategies. Since the 1990s strategies have focused on outsourcing, offshoring, and lean manufacturing to cut costs, retain a market position, and/or gain competitive advantage (Simchi-Levi & Haren, 2022). Following the last year's disruptions, new strategies focused on reshoring or nearshoring have gained more interest because they facilitate agility and improve the resilience (Rojas et al., 2022).

Reshoring is known as the process of returning the manufacturing and production of goods and products to the company's original country (Kenton, 2021). While nearshoring is when businesses move their operations to a nearby country from one further away (Young, 2019). For the container shipping industry, the main aspect of reshoring and nearshoring is moving production away from China, which since the 1990s has been the main global manufacturing hub.

In 2019, China accounted for 28.7 percent of global manufacturing output (Simchi-Levi & Haren, 2022). Even though companies after the SARS epidemic of 2003, the financial crisis in 2008, and the tsunami in 2011 recognized that the strategies developed in the 1990s could expose them to operational problems (Simchi-Levi & Haren, 2022), the numbers of manufacturing output show the importance of China. China is the largest exporter and producer of industrial goods, contributing 39.18 percent of its GDP in 2020, and at the same time the second-largest importer after the US (Siqi, 2021). Shipping is China's most important transportation method, with the country having seven of the world's top ten container ports (Figure 12) and around 400 smaller ones as well (Siqi, 2021). In 2020 merchandise worth 2.5 trillion dollars was imported to and exported from China by ships, accumulating to 53 percent of their total trade, and being higher than transport by air, rail and road combined (Siqi, 2021). China is also the world-leading builder of ships and containers. Of the world total, China delivers around 45.6 percent of ships and over

96 percent of containers (Siqi, 2021). Container shipping from China is a huge industry and is of severe importance to the global economy. However, when circumstances such as the pandemic and Suez Canal blockage occur businesses dependent on Chinese production and shipments by sea start to reconsider their strategies.

COVID-19 and the other disruptions in global SCs involving container shipping have shown several factors SCs need to consider when moving forward. Reducing risk and vulnerability while increasing resilience is mentioned as one of the key objectives for the future (Rojas et al., 2022). In connection with this, one possible way to achieve this could be onshoring. Frederico Duarte, Director of SC Operations for Baker Hughes stated this: "Whether it is a war, a tsunami, another pandemic, or even snow that closes airports, an event like COVID-19 that affects global business will certainly happen again. Businesses must invest, diversify, and build greater resilience into their SCs than they currently have if they are to mitigate the risks. We must have not only a Plan B but also Plans C and D ready to roll" (EtonBridge, 2020). SC disruptions will occur again, and without reconsidering strategies and business models' companies may not survive new situations like the pandemic, the Suez Canal blockage, and the War in Ukraine caused. For the shipping industry, which is highly dependent on Chinese manufacturing, this could be a huge challenge to volume and throughput, affecting the profit.

While some companies most likely will reshore or nearshore to deal with future challenges, others will probably stick to Chinese production. Companies choosing to stay could take other measures to improve their business strategy and model, to improve resilience and reliability to deal with future disruptions. As a reaction to companies decentralizing their manufacturing capacity, China focuses on technology-driven and high-value industries to power their next growth cycle (Nakhoda, 2021). One example of this is the smart command and control center project based on remote control that Shanghai International Port Group (SIPG) launched in 2021. The project was launched in Yangshan Port, the world's largest and most automated container terminal (Port Technology, 2021). With remote control of the terminal, the throughput of containers isn't affected by restrictions and lockdowns. The terminal's capacity is the same as before or even improved, and reshoring or nearshoring is therefore not necessarily the best strategic decision for

companies trying to develop and deal with disruptions. In April 2022 Shanghai was in lockdown again, as much as three years after the first outbreak (Brant, 2022). It is likely to believe that the remote-control system is key in helping the port affected by restrictions and lockdowns keeping the capacity of container handling and throughput on a high level.

Reshoring has grown as an important strategy to deal with the resilience and reliability issues caused by disruptions (Rojas et al., 2022). On the other side, the costs and logistical challenges with reshoring may be prohibitive for many firms. Therefore, another possibility to increase the reliability and resilience in the industry could be the implementation of technologies that enhance transparency, collaboration, flexibility, and velocity.

Chapter 5 – Discussion

After the analysis, a matrix (figure 22) has been created to show the impact each of the examined disruptions has had on the container shipping industry. Each disruption is given a score from 0-5, where 5 is a very high influence and 0 is no influence. The points are given based on the analysis and findings in the previous chapter and scores how each of the disruptions has affected demand, closed borders and ports, lack of drivers, container shortages and increased prices.

	COVID-19	The Suez Canal blockage	The War in Ukraine
Increased demand	4	0	0
Closed borders and ports	5	0	1
Lack of drivers	3	0	1
Container shortages	5	3	0
Increased prices	5	5	2
Total	22	8	4

Figure 22: Impact matrix

The matrix gives COVID-19 a total score of 22, The Suez Canal blockage a score of 8 and the War in Ukraine a score of 4. The pandemic has influenced the container shipping industry in a significant matter and the impact has been severe. The pandemic has disclosed how vulnerable the industry is, especially regarding the need for a human workforce. Lockdowns, quarantine requirements and closed borders and ports have resulted in container shortages and increased container freight rates. During the lockdowns, people shifted away from spending money on services such as restaurants, cinemas etc. resulting in people having more funds to use on other things. Peoples purchasing behaviours changed, and people started buying more things online, started to renovate their houses and investing in things that would make life better at home. These changes resulted in an increased demand for containers because the majority of the wanted products were transported by container ships.

The pandemic was also the direct reason for a lot of closed borders and ports, increasing the waiting time for ships to be able to enter the ports and making severe congestions. In addition, countries and governments were afraid of the spreading of the virus and introduced quarantine requirements which resulted in the workforce all over the industry suffering. Consequently, the efficiency at ports was reduced when it needed to be increased. This created bottlenecks in the supply chain and resulted in long lead times, shortages of containers and increased prices. The ongoing issue of lack of truck drivers in the industry was also additionally increased because of COVID-19. Creating congestions on land in and out of the ports as well.

In addition, China, which is one of the biggest exporters of container goods in the world, coped with the virus much faster than anyone else. When China had already dealt with the virus, other countries started to enter the lockdowns. They were ready to sell products again while people in the rest of the world were stuck in their homes and started to spend more money on electronics, furniture, exercise equipment etc, products typically produced in China. Consequently, a lot of products were leaving China as normal, but the containers were not coming back. The rest of the world operated under strong restrictions with a lack of both general export of products and lack of labour in ports, and containers got stuck in the west while they were needed in Asia. There were fewer loaders, drivers, crane operators and terminal workers at

the ports, making the efficiency at the ports slower. Because of the tight schedule for ships, this resulted in the ships leaving with fewer containers on the way back to Asia compared to what they transported to the west. The shortage of containers caused the prices for containers to spike. In the middle of the chaos with shortages of containers, skyrocketing transportation prices and trade imbalance between Asia and the west, the Suez Canal blockage occurred. This canal is part of the Asia-Europe route and caused the prices to increase even more. Even though the Suez Canal blockage and War in Ukraine score relatively low on the impact matrix shown in figure 22, it is important to recognize that these events came on top of the pandemic, causing the overall impact to be even greater.

The paper has so far introduced the influence the disruptions have had on the container shipping industry. In the next part of the discussion, the authors investigate how the industry can prepare itself for disruptions in the future. To substantiate the discussion, the chapter begins by introducing how the container shipping industry operates. Moreover, the chapter elaborates on how disruptions like COVID-19, have worked as a technological accelerator, where companies have accelerated customer and SC interactions and internal operations by three to four years (LaBerge et al., 2020). Lastly, the chapter contains a discussion on how the use of new technologies can help companies improve their risk management and increase resilience and reliability.

5.1 Container Shipping Industry

Thousands of containers from countries all around the world arrive at seaports every day. Each shipment represents a specific SC that is unique, and it all starts with an order (World Shipping Council, n.d.). A store places an order for a product, and a freight forwarder arranges transport from the factory. A trucking company arrives at the factory and loads orders into a container. The container is closed until arrival at the distribution warehouse. The freight forwarder determines where it is most economical to ship the container from, and the container arrives at this port where it is loaded onto a ship, and the big journey begins. The container ship is bound for a discharge port on another continent. After receiving proper clearance to arrive at the port, the vessel docks next to large cranes used to unload the container. Qualified dockworkers operate the cranes. When the container is cleared by customs, workers

load the container onto special trucks, chassis or trains that transport the container to the distribution center. At the distribution center, the container is opened and orders are individually separated and prepared for shipment to the respective customers (World Shipping Council, n.d.).

It takes 3,000 people working for three days to unload and load a giant container ship with the capacity for 20,000 containers (Sudal, 2018). The ports are hence a very important intermediate in the container shipping industry, where most of the static waiting time occurs. Therefore, improvements at the ports could have a significant impact on the container shipping industry, by reducing time spent at ports and eventually resulting in less congestions. The world's biggest container-ship operator, A.P. Moller-Maersk, is adopting new digital techniques to get the vessels in and out of ports as quickly as possible, ultimately aiming to eliminate bottlenecks in SCs (Sudal, 2018). Due to the importance of the container ports, the authors will in the next sections provide a more detailed explanation of how the container ports work.

5.2 How does a container port work?

Containers are considered one of the greatest inventions of the modern world and are defined as a standardized 20, 40, or 45-foot long foot steel receptacle that houses any variety of goods (Peterson, 2015). Standardized global containers following the ISO (International Organization for Standardization) standard work on essentially any ship, truck, or railcar fitted for them (Peterson, 2015). By using standardized containers, the industry prevents concerns and problems such as how to pack a ship, what's on it, if the containers will fit on specific trucks, etc. Moreover, the development of containers revolutionized trading among nations and global trade in general (Peterson, 2015). Increasing trade between nations by as much as 320 percent in 5 years since containerization started in the 1960s, and as much as 790 percent in 20 years (Peterson, 2015). In connection with this, the shipping industry, especially container ships and terminals had to reinvent and reimagine its business to deal with the massive increase in trade. But how does a container terminal handle the containers arriving?

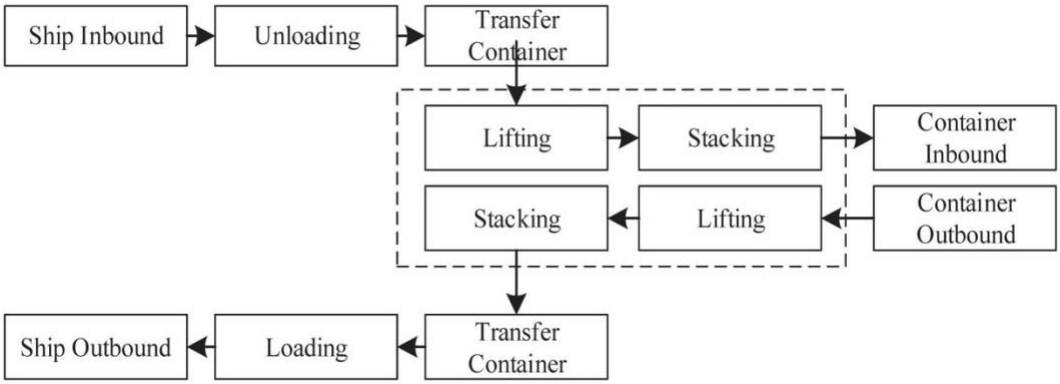

Figure 23: Container terminal (Budpriyanto et al., 2017).

The model above shows the container handling process at a container terminal. In general, the terminal operations consist of ships inbound and outbound, quay cranes discharging and loading systems, internal transportation and container movements, container yard discharging and loading systems, stacking systems, and inbound and outbound processes for containers (Budpriyanto et al., 2017). Furthermore, the big terminals use systems where incoming ships are expected to follow a regular schedule, and in ideal circumstances, the ships arrive by a predetermined time (Budpriyanto et al., 2017). Understandably this is a complex operation, and therefore ports have started to explore how they can improve their capabilities and business with help of new technologies.

5.2.1 Shift from physical to digital infrastructure

With new technologies, infrastructure expansions at ports do not necessarily need to happen physically anymore, but rather with the adoption of digital Smart Port solutions to cope with the growing marketing and industry expansion (Nakhoda, 2021; Sinay, 2021c). Following this, the industry shifts toward utilizing existing infrastructure and facilities to their fullest potential to deal with capacity constraints, instead of new physical constructions (Nakhoda, 2021; Sinay, 2021c).

Physical ports are constructed with a plan for possible future expansion stages, having engineering plans ready for increased cargo volumes (Sinay, 2021c). With increased demand and importance of ports, and logistic performance becoming more and more important for competitiveness, port infrastructure is more crucial than ever. Digitalization could be a solution to expansion dealing with increased

demand without bringing further environmental impact to the surrounding areas (Sinay, 2021c).

5.2.2 Port 4.0

With shipping carrying 90 percent of world trade and having a steady growth of 4 percent per year, the interest in developing Smart Port systems and utilizing information and communication technologies, increases significantly (Yau et al., 2020). Despite different sizes of ports and various kinds of initiatives for improvements, the transition to port 4.0 often includes using new technologies, with the most common and important technologies being robotics, AI, Big Data, IoT, Blockchain Technology, and 5G (Nakhoda, 2021; Sinay, 2021b). These industry 4.0 technologies are often mentioned when it comes to the future digital SC and are thus important for the future of the container shipping industry.

As ship sizes grow, the world's population rises and the importance of goods to move faster increases, developing ports and making them more efficient and competitive becomes a necessity and not just an option anymore (Nakhoda, 2021; Sinay, 2021b). The global technological revolution forces ports to develop their business structure and infrastructure, something Smart Ports facilitates with the use of new digital solutions (Nakhoda, 2021; Sinay, 2021b; Yau et al., 2020). Disruptions such as COVID-19, the Suez Canal and the War in Ukraine drive the development and show the importance of improving operational capabilities in ports. Hence, the development of port 4.0 to be more effective, more performant, and more economically competitive is important for the industry (Nakhoda, 2021; Sinay, 2021b; Yau et al., 2020).

Port 4.0 will be powered by AI, optimization through advanced analytics, and dynamic scheduling (Chu et al., 2018). McKinsey and Company analyzed how port 4.0 could improve operations connected to real-time berth planning, predictive maintenance for key assets, automated yard planning, and demand planning at the gate (Figure 23).

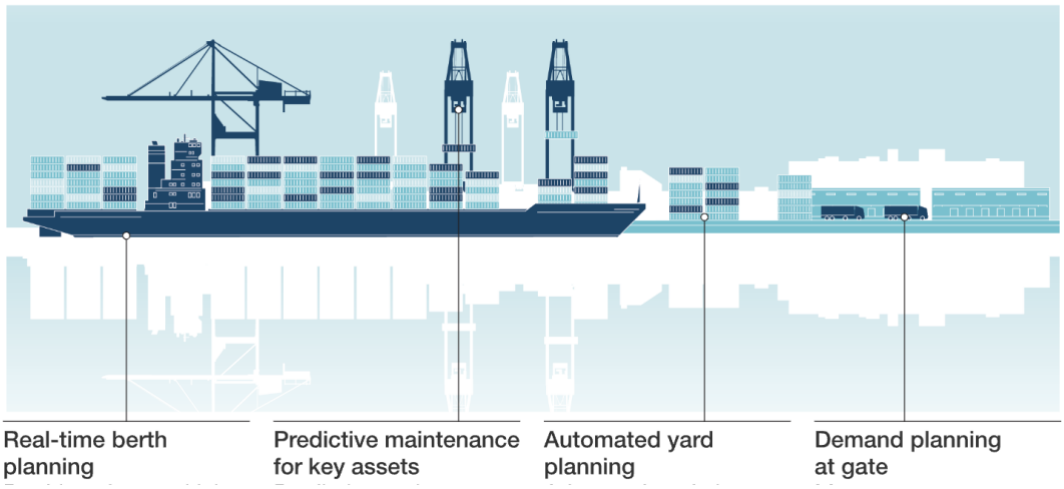

Figure 24: Port 4.0 (Chu et al., 2018).

When it comes to real-time berth planning technologies enhance that slots and labour can be better used by more accurate forecasting of ships arrival time. This can result in potential earnings before interest, taxes, depreciation, and amortization (EBITDA) increasing the potential of up to 8 percent for terminals. Remote and predictive crane and vehicle maintenance can lead to a 30-50 percent reduction in machine downtime. This will be beneficial for increasing the availability of important assets such as ship-to-shore and rubber-tired gantry cranes, which again increase efficiency. Automated yard planning with the use of advanced analytics and modelling makes it possible to swap assets, reroute containers dynamically, and adjust routing and speed in real-time. Demand planning at the gate gives more accurate predictions of consumer and production behaviour, which can better help container terminals estimate demand for the gate arrivals (Chu et al., 2018). These improvement areas are central for port 4.0 and will facilitate developed operational capabilities in ports, which again will advance SC performance.

5.3 Technological acceleration

COVID-19 caused a lot of problems for SCs, and businesses all over the world. As a result of this, companies in all sectors and regions have reshaped how they conduct business (LaBerge et al., 2020). According to McKinsey's Global Survey of executives, the companies questioned have accelerated the improvement of customer and supply-chain interactions and internal operations by three to four years with the use of technologies (LaBerge et al., 2020). Moreover, the executives in the survey conducted by McKinsey say that the technological revolution

happened faster than they believed was possible and that they expect the changes to last (LaBerge et al., 2020). These changes apply to every business sector, especially the shipping industry where COVID-19 forced shipping to adopt technologies not used in the industry more rapidly (Belokas et al., 2021).

The resilience of SCs was under severe pressure during COVID-19. However, technologies in the heart of industry 4.0 helped shipping companies and SCs to survive the pandemic (Umbarkar et al., 2021). The value of technologies has already been proven during the challenges that occurred during COVID-19, the Suez Canal blockage, and the War in Ukraine. Therefore, developing the industry with the use of new technologies, and reimagining strategies and practices is more important than ever before. Staying competitive is harder than before following the new business and economic environment caused by the aforementioned disruptions. For this reason, recognizing technologies that can have strategic importance is critical for every business (LaBerge et al., 2020).

Government restrictions during the pandemic forced consumers from physical to online channels, forcing companies and industries to respond. Furthermore, the technological imperative is more urgent than ever because of the COVID-19 crisis (LaBerge et al., 2020). Overall strategy and strong leadership have been markers for success when dealing with earlier disruptions and transformations, in contrast, technology differentiating has been the most important marker during the pandemic (LaBerge et al., 2020). In the maritime sector implementation of industry 4.0 technologies have great possibilities. As stated in the literature it can be beneficial when it comes to transparency, operations, and improving the working environment. During COVID-19 the shipping industry experienced container shortages, partly due to decreased efficiency in the operations of emptying them. Better transparency and improved operations by using technologies could resolve the issue of shortages of containers. With increased efficiency, a larger number of containers could be emptied in a shorter time. Consequently, fewer containers would be stuck, and the experienced shortage could be less serious for the economy of the world. However, increased efficiency would not necessarily resolve all problems that led to shortages but could improve the situation to some extent. Furthermore, the Suez Canal blockage and the War in Ukraine escalated the shortage of containers. Despite technologies not solving all the problems that

caused resilience issues for SCs and the container shipping industry companies have seen the significance utilizing technologies can have.

Mike Konstantinidis, Chief Executive Officer of METIS Cyberspace Technology, states that "COVID-19 has been a catalyst in the digital transformation procedure" (Belokas et al., 2021) when talking about COVID-19 and technologies in the shipping industry. The global pandemic brought more negative than positive aspects, but when it comes to how it influenced the shipping industry's digital journey it is safe to say that the effect was positive. Moreover, the container shipping industry has seen the potential of technologies and experienced how they could help them deal with disruptions. For this reason, the technological implementation in the industry is likely to have accelerated because of COVID-19 and the other mentioned crises.

Simon Fotakis, the CTO of Tototheo Maritime says regards to if shipping will revert to its traditional way: "If you were given a smartphone while you were sick, would you give it back after you are healthy? Probably not. With that example, I wish to say that I do not see shipping reverting to its traditional ways" (Belokas et al., 2021). So why should the industry revert to its traditional ways when the acceleration of technologies has shown a new and better way forward.

5.3 Risk management

The disruptions discussed in this paper reveal how vulnerable the global SC is when unforeseen events occur. While the disruptions mentioned in this paper could be hard to avoid, it is possible to influence the consequences that follow. Risk management relates to the ability to identify risks that might arise from such events, the capability to judge the consequences, how to treat the risks and how to monitor the identified risks.

With the use of new technologies such as AI, blockchain, big data, IoT and 5G, the identification of risks can be easier and more accurate. Data can be used to make predictions on the effect of disruptions, and hence estimate the following risks. In addition, the technologies can be used to assess the risks in terms of severity and probability of the event occurring. The assessment is based on relevant data, expert

opinions, or scenario thinking, all improved using technologies. When the risks are identified and assessed, the handling of the risks is important. In this part of SCRM, the goal is to reduce risks to an acceptable level. In the event of COVID-19, the industry experienced that borders and ports closed, resulting in port congestions and shortages of containers. The lack of human workforce due to people being infected by the virus and quarantine requirements was a big issue during the pandemic. Automated ports could have reduced the need for human workforce and hence helped to reduce the risks. Successful automated ports could raise productivity by up to 35 percent (Chu et al., 2018), enabling the ports to handle containers much faster. The port congestion could be less severe, and the overall risks associated with the pandemic could have been reduced. The last part of the SCRM process is to monitor the risks after they have occurred. Here, technologies could be of major benefit to the industry, being able to monitor risks in real-time and help to react faster when changes occur.

5.4 Resilience

5.4.1 Collaboration

Collaboration and transparency across SC entities have in a more globalized business world become more important than ever (Christopher, 2016). Building resilience in the industry requires transparency, information sharing, and coordination across all entities. To achieve this involved parties must be committed, build trust, and collaborate (Christopher, 2016). With the use of technologies that facilitate transparency, openness, dynamic networking and connectivity accomplishing this could be simpler. Different technologies within industry 4.0 enable SC partners to interact and collaborate – something that could help increase resilience.

Blockchain is one technology that could increase the overall trust and transparency within the industry. By simplifying the decision-making processes at every stage since partners can audit at the same time making real-time optimization possible (Yang, 2019). Another benefit the industry could extract from the use of blockchain technology is monitoring and tracking the goods throughout the whole chain and open access to the delivery time information (Tapscott & Tapscott, 2018). The need for collaboration and trust when tracking goods between all entities such as

shippers, ocean freight forwards, shipping carriers, maritime port corporations, terminal operators and customs offices are of severe importance for SC performance. In industry 4.0 5G technology is a central component that can support transparency and connectivity between relevant partners (Dolgui & Ivanov, 2022). Implementing the use of both blockchain technology and 5G technology in the container shipping industry will enable partners to collaborate better by increasing transparency making it easier to build trust. By using these technologies, together with an openness to extract the benefits they embrace, collaboration in the industry could be improved. The enhanced collaboration will be the first and an important step for the industry to increase its resilience.

5.4.2 Visibility

To achieve strong collaboration and further improve resilience in the industry the aspect of visibility between relevant entities is important (Christopher, 2016). Realizing visibility is dependent on information sharing from one end to another in real-time with the highest possible accuracy. Since visibility is strongly correlated with stronger relationships, trust and transparency are important factors to boost visibility and collaboration. Blockchain, AI, IoT and 5G could help the industry develop and improve the overall visibility between partners.

Big data analytic tools help with storing and processing real-time data. In the maritime industry, you have a significant amount of data generated in navigation systems through radar, electronic chart display and information systems, auto-pilot systems, and sensors in the general (Perera & Mo, 2016). Collecting data from different sensors and analyzing them provides information that supports decisions making which could improve energy efficiency and system reliability (Miličević et al., 2018). Together with 5G technology, which enhances SC visibility, big data could help increase information sharing of real-time data. In order, by increased visibility and information sharing with the use of these technologies, the industry could gain better decision-making and control when needed to intervene quickly (Dolgui & Ivanov, 2022; Torre-Bastida et al., 2018). Another beneficial industry 4.0 technology for improved visibility is blockchain technology. Blockchain technology could provide time stamps to prove data exchange and visibility (Czachorowski et al., 2019). Following this, with the use of big data, 5G, and

blockchain technology full visibility between SC partners is possible, something that will facilitate the improvement of SC resilience.

5.4.3 Flexibility

Information sharing and collaboration between entities in an SC are important aspects to enhance the flexibility (Christopher, 2016). The maritime sector operates using an information network involving many parties such as shippers, freight forwarders, port operators, and carriers. As a result of this, the industry often has bias and information asymmetry (Kelly, 2022). Information asymmetry and lack of bias between the entities in the industry reduce flexibility and therefore also resilience. Technologies could enhance information sharing and collaboration, something that in order increases flexibility in the industry.

Blockchain technology consists of a distributed database that is shared among entities and maintains a growing list of data records that are confirmed by the nodes participating in it. Further, it provides security and data integrity without any trusted third party involved (Hayes, 2022). With fewer people involved and independent of any third parties, you become more flexible, all enabled by blockchain technology. Another technology directly affecting the flexibility is 5G, which is "an instigator and enabler of end-to-end connectivity between organizations, processes, and devices which can be achieved in real-time at a highly granular level and so contribute to end-to-end visibility and flexibility through the Internet of Things" (Dolgui & Ivanov, 2022). Implementation of blockchain, 5G, and IoT could contribute to increased visibility and flexibility – something that will increase the resilience of the industry.

5.4.4 Velocity

Velocity is a key aspect in the foundations for a responsive SC, which refers to responding more rapidly to SC changes, recovering and adapting consequently (Christopher, 2016; Jüttner & Maklan, 2011; Ponomarov & Holcomb, 2009). Based on this, velocity is a key competence for SCs when confronting disruptions (Mandal et al., 2016). Further, Scholten & Schilder (2015) state that velocity provided sufficiently and the right information could reduce response and recovery times when facing issues.

The last aspect being highlighted to achieve SC resilience is velocity, which is responding promptly to SC changes, and recouping and adjusting consequently (Christopher, 2016). Responding sufficiently to changes in the industry is strongly affected by collaboration, visibility, and flexibility. Therefore, the aforementioned areas of improvement that the industry 4.0 technologies contribute to are highly relevant here as well.

If companies within the industry successfully build trust, transparency, and information sharing they will be able to collaborate and increase visibility. In turn, this will enable improved flexibility, which again increases the aspect of velocity. Extracting benefits from the discussed technologies will lead to better operation and performance due to increased flexibility, responsiveness, and improved adaptability which in the end forms the basis for a resilient SC.

5.5 Reliability

The analysis of reliability during the disruptions revealed that reliability in the container shipping industry was exceptionally low. Container ships were more delayed than ever, something that strongly affected the business world and maritime industry. Low reliability could indicate that delivery reliability, as well as customer- and supplier relationships were not good enough to deal with the disruptions. How to increase reliability is therefore of severe interest, especially since reliability becomes an important global theme in response to the SC issues experienced since the outbreak of COVID-19.

Delivery reliability of containers and products has been extremely low since the outbreak of COVID-19 and additionally worsened by the Suez Canal blockage. Mainly due to government restrictions with closed borders and ports and a lack of workforce. Consequently, the industry must consider options requiring less workforce to avoid suffering from low delivery reliability in the future. With the implementation of the industry 4.0 technologies robotics and AI some of these issues could be handled better. Firstly, cranes integrated with AI technology called Automated Robot Cranes (ARC) can perform tasks connected to containers either autonomously or controlled remotely by humans (Global Infrastructure Hub, 2020).

In periods of lockdowns and lack of workforce such cranes would be highly beneficial to maintain the operations at container terminals, something that could help the overall delivery reliability. At the same time, robotics could increase operating productivity by up to 35 percent (Chu et al., 2018), which also directly could help the terminals deal with efficiency loss due to lack of workforce.

Another beneficial technology strongly correlated with robotics is AI, which is "the simulation of human intelligence in machines that are programmed to mimic their actions" (Frankenfield, 2020). AI is considered the main enabler for port automation, and could for example automate and optimize mundane and routine tasks (DeChant, 2020). With the use of AI, the industry could increase the efficiency in ports and decrease the number of people needed to operate a container terminal. This is something that could help the industry in the future when handling similar disruptions as COVID-19 and the restrictions that followed. Further improvement AI offers is the use of machine learning, which plugs real-time data from blockchains and IoT sensors into AI algorithms. By doing this you can track vessels and therefore know the accurate estimated time of arrival (ETA) for ships (Sinay, 2021a). With this data, container terminals could optimize berthing time and by this improve operational capabilities. With the use of these technologies, the industry could maintain its delivery reliability even during disruptions.

Within SC reliability the other important aspects are customer- and supplier relationships. Strong relationships across the SCs and between all entities are highly important and closely related to elements of resilience. Industry 4.0 technologies enabling SC transparency, trust, collaboration, visibility, and flexibility are key improvement areas to handle future disruptions that could cause reliability issues.

Chapter 6 – Conclusion

The authors of this master thesis have investigated how disruptions like COVID-19, the Suez Canal Blockage and the War in Ukraine have influenced the container shipping industry and examined how the industry can prepare for disruptions in the future. First COVID-19, which is considered the most severe SC disruption the world has experienced ever, hit, and the world experienced national lockdowns

quarantine requirements and closed borders and ports. The pandemic hit a world unprepared for its ramifications. Purchasing behaviours shifted from services to goods, increasing the demand for container space. Infected people, quarantine requirements and lockdowns resulted in labour shortages all over the industry, making it impossible to handle the increased demand. The above mentioned factors together caused congestions at ports and delays of container vessels, resulting in a severe shortage of containers. The shortage of containers caused prices for container space to increase dramatically, making it extremely expensive to transport goods. The already known problem of truck driver shortage was amplified during the pandemic, increasing problems for the industry further. Truck drivers are a critical workforce for moving shipments from one point to another onshore. When the pandemic created backlogs in ports the demand for truck drivers increased. Therefore, the availability of trucking was reduced during the pandemic slowing the process of moving the goods out of the ports.

The next disruption influencing the industry was the Suez Canal blockage that hit an industry still trying to recover from the pandemic, increasing some of the disturbances and setbacks from the pandemic. Average monthly delays for container vessels were starting to decrease again after an all-time high during the pandemic until late March 2021, when the Suez Canal blockages occurred. The blockage, together with the delta version of the virus, dominating from May 2021, resulted in delays rising to an all-time high. The container freight rates also spiked from late March 2021, continuously increasing from USD 4,872 to as much as USD 10,361 in September 2021. From a more than doubling of freight rates in just a few months, businesses all over the world suffered, ultimately resulting in increased prices for the end consumer.

The War in Ukraine is relatively recent, and the impact it has had on the industry is hence difficult to determine, however, the authors want to highlight some of the key takeaways from the research. Shipping companies were earning a substantial amount of money because of the high prices for container space, but when the War in Ukraine occurred the prices for oil and energy increased. Something that will most likely affect the profitability of shipping companies due to the influence the price increase has on the cost of transporting goods. Another more substantial consequence of the War was that the Russian forces were shutting off shipping

routes and that Russian logistic companies had to suspend their services. Cargo movements were also made impossible in essential Ukrainian ports because they were closed, damaged or under attack. The last, and maybe most severe disturbance is yet to be identified. Russia and Ukraine account for 14,5 percent of the global shipping workforce, and the war can hence result in a shortfall in shipping crew.

The disruptions have tested the reliability of the industry and showed the importance of resilience. Even though most firms usually have contingency plans, no one was able to anticipate the severe consequences of the discussed disruptions. This shows the importance of risk management and the ability to manage disruptions when they occur. The research has identified technologies as important instruments to help the industry to be better prepared for and handle disruptions. The pandemic was a technological accelerator, and the technological revolution happened faster than people believed possible confirming the significance of new technologies. The pandemic has shown how dependent the industry is on human workforce. Robotics together with AI can create automated ports reducing the need for human workforce. An automated port can be controlled remotely, operations work despite less people at work and the terminal can handle containers 24/7. Ultimately, the ports could experience an increase in productivity of up to 35 percent (Chu et al., 2018), reducing congestions and delays significantly. Our research showed that ports that had implemented 4.0. technologies before the pandemic managed better compared to ports that had not.

Technologies can also enable real-time data sharing between SC entities, which makes it easier to track goods throughout the whole chain, and better facilitate planning and operation management in ports. Real-time data sharing enhances transparency, collaboration, and trust in the SC and increases both flexibility and reliability. During the disruptions, the reliability of container shipping was low, and everyone dependent on container shipping experienced severe delays and high prices. Improved transparency, information sharing, and collaboration also increase the resilience of the SC and make it easier to recover quickly after disruptions.

In conclusion, there is little doubt that the mentioned disruptions have severely influenced the container shipping industry, labour shortages, container shortages and increased prices being the most significant consequences. The research also

shows the importance of technology in the industry and therefore technologies and automated ports are believed to be the best solution to prepare for disruptions in the future.

Chapter 7 – Limitations

Before beginning working on the master thesis, the authors knew there would be some limitations to the research and research area. Limitations refer to the limited amount of previous research and literature conducted on the topic. When researching this topic, the authors found a lack of research about how disruptions impact the container shipping industry, especially when it comes to resilience and reliability. Moreover, there is not a lot of research on improvement areas that could help the industry deal with disruption-related issues. Another limitation to our research is that the analysed disruptions are due to recent events, and therefore literature about how they have influenced the container shipping industry is limited. This applies especially to the most recent event, the War in Ukraine but also to the long-term impact of COVID-19 and the Suez Canal blockage.

With the disruptions all being relatively recent events the available data about impact is limited and the long-term impact on for example freight rates is unavailable. Furthermore, the technologies discussed in this paper are technologies in the early stage of adoption in all industries, especially the maritime industry. Therefore, there are limited practical and real examples of how beneficial the implementation could be. The authors research about the technological application of industry 4.0 technologies is not fully comprehensive as the authors have limited knowledge of the technical part of the different technologies.

Another limitation of this study is the use of only secondary data in the collection of data. Even though the data is confirmed by several sources stating the same, primary data collection could have further improved the quality of the research.

Chapter 8 – Future research

Considering the events discussed in this paper to be relativity recent, all the effects the disruptions have had on the industries are not yet possible to identify. Further research should be done when there is more data available, and when the industry has bounced back to its new ´normal´. Only when the congestions and shortages of containers are over, and rates have stabilised, the total effect of the disruptions can be measured. Moreover, after conducting thorough research and considering the limitations, the authors recommend that researchers conduct further studies about the implementation of industry 4.0 technologies in the container shipping industry. In future research, the quantification of benefits and costs regarding implementation would be interesting. Following this, research should also focus on distribution of costs across the SC entities since the technologies require or invite to collaboration.

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