



Postgraduate Programme of Studies

Supply Chain Management

(S.C.M)

Hellenic Open University

Postgraduate Dissertation

“Disruptions in supply chains under unpredictable external factors
and the effects on the maritime industry.”

Alexandra Matzana,

Std511070

Supervisor's name: Dr. Konstantinos Antonopoulos

Patras, Greece, June 2023

Theses / Dissertations remain the intellectual property of students (“authors/creators”), but in the context of open access policy they grant to the HOU a non-exclusive license to use the right of reproduction, customisation, public lending, presentation to an audience and digital dissemination thereof internationally, in electronic form and by any means for teaching and research purposes, for no fee and throughout the duration of intellectual property rights. Free access to the full text for studying and reading does not in any way mean that the author/creator shall allocate his/her intellectual property rights, nor shall he/she allow the reproduction, republication, copy, storage, sale, commercial use, transmission, distribution, publication, execution, downloading, uploading, translating, modifying in any way, of any part or summary of the dissertation, without the explicit prior written consent of the author/creator. Creators retain all their moral and property rights.



“Disruptions in supply chains under unpredictable external factors and the effects on the maritime industry.”

Alexandra Matzana

Supervising Committee

Supervisor:

Dr. Konstantinos Antonopoulos

Advisory Teaching Staff, HOU

Co-Supervisor:

Thomas Dasaklis

Assistant Professor, HOU

Patras, Greece, June 2023

“Education without application is just entertainment”- Tim Sanders

Abstract

The shipping industry has always had a globalized character due to the nature of the business. Transportation of merchandise through vessels has extended the supply chains to cover all parts of the world thus increasing its complexity and turning the supply chains sensitive to disruptive events such as natural disasters, pandemics, as well as accidents that affect the infrastructure. The purpose of the study is to analyze data from the industry related to disruptive events such as a global pandemic like COVID-19, and the Suez Canal Blockage-21 and showcase how such events can disrupt the maritime supply chain and to what extent. The objective is to identify the causes of the disruption in order to identify how the maritime supply chain can increase its resilience to such events and how their possible losses can be mitigated, if possible. A thorough literature review will be conducted in order to understand the extent to which the maritime supply chain has been affected by disruptive external factors. Historical data of the volumes transported via the maritime industry and the routes that are included in this type of industry will be studied to understand the geographical locations, either that is a canal in the case of the Suez Canal Blockage-21, or a global phenomenon like COVID-19.

Keywords

Global supply chain disruptions, Supply Chain Resilience, Global maritime transportation, Supply Chain Risk Management

Περίληψη

Η ναυτιλιακή βιομηχανία είχε πάντα έναν παγκοσμιοποιημένο χαρακτήρα λόγω της φύσης της επιχείρησης. Η μεταφορά εμπορευμάτων μέσω πλοίων έχει επεκτείνει τις αλυσίδες εφοδιασμού για να καλύψει όλα τα μέρη του κόσμου, αυξάνοντας έτσι την πολυπλοκότητά της και μετατρέποντας τις αλυσίδες εφοδιασμού ευαίσθητες σε ανατρεπτικά γεγονότα όπως φυσικές καταστροφές, πανδημίες, καθώς και ατυχήματα που επηρεάζουν την υποδομή. Σκοπός της μελέτης είναι να αναλύσει δεδομένα από τη βιομηχανία που σχετίζονται με ανατρεπτικά γεγονότα όπως μια παγκόσμια πανδημία όπως αυτή του COVID-19 και την εμφραξη της διώρυγας του Σουέζ και να δείξει πώς τέτοια γεγονότα μπορούν να διαταράξουν τη θαλάσσια αλυσίδα εφοδιασμού και σε ποιο βαθμό. Ο στόχος είναι να εντοπιστούν τα αίτια της διακοπής προκειμένου να εντοπιστεί πώς η θαλάσσια αλυσίδα εφοδιασμού μπορεί να αυξήσει την ανθεκτικότητά της σε τέτοια γεγονότα και πώς μπορούν να μετριαστούν οι πιθανές απώλειές τους, εάν είναι δυνατόν. Θα διεξαχθεί διεξοδική βιβλιογραφική ανασκόπηση προκειμένου να κατανοηθεί ο βαθμός στον οποίο η θαλάσσια αλυσίδα εφοδιασμού έχει επηρεαστεί από διασπαστικούς εξωτερικούς παράγοντες. Τα ιστορικά δεδομένα των όγκων που μεταφέρονται μέσω της ναυτιλιακής βιομηχανίας και των διαδρομών που περιλαμβάνονται σε αυτόν τον τύπο βιομηχανίας θα μελετηθούν για να κατανοηθούν οι γεωγραφικές τοποθεσίες, είτε πρόκειται για κανάλι στην περίπτωση του αποκλεισμού της διώρυγας του Σουέζ, είτε για παγκόσμιο φαινόμενο όπως το COVID-19

Λέξεις – Κλειδιά

Διάσπαση Εφοδιαστικής Αλυσίδας, Ελαστικότητα, Παγκόσμιες Θαλάσσιες Μεταφορές

Table of Contents

Abstract	v
Περίληψη.....	vi
Table of Contents	vii
List of Figures	viii
List of Abbreviations & Acronyms	ix
1. Introduction	1
1.1 Background.....	1
1.1.1 Cases of Disruption	4
1.1.2 Analyzing the issue	6
1.1.3 Purpose of this dissertation	7
1.2 Literature Review	7
1.2.1 Managing Risks through Resilient Supply chains	7
1.2.2 The susceptibility and interruptions of the supply chain.....	8
1.2.3 Dynamic and Operational Capabilities	11
2. The worldwide shipping network.....	13
2.1 Port Operators	15
2.2 Maritime Shipping Companies	17
2.3 Freight Forwarders	17
2.4 Land Transportation	18
2.5 Building Resilience in the Maritime Supply Chain	19
2.5.1 Port Handling	20
2.5.2 Land Operations	23
2.5.3 Ocean Freight.....	23
3. Risks Associated with Disruptions in Supply Chain.....	25
3.1 Supply- Side Risks	25
3.2 Demand – side Risks	27
3.3 Operational Risks	29
3.4 Environmental Risks	30
3.4.1 Calamities.....	31
3.4.2 Accidents.....	32
3.4.3 Political Instability – Regulatory Restrictions	33
3.4.4 Diseases- Pandemics and Epidemics	33
4. Global Impacts	35
4.1 Impacts on the global supply chain from COVID-19	35
4.1.1 Alterations in the Markets	35
4.1.2 Capacity Shortage	36
4.1.3 Long term developments.....	37
4.1.4 Lessons learned- Resilience	38
4.2 Impacts due to Suez canal blocking	38
4.2.1 Re routing.....	39
4.2.2 Interaction with the Media	39
4.2.3 Lessons learned- Resilience	39
5 Conclusion.....	41

References	43
------------------	----

List of Figures

Figure 1 : Supply chain resilience through the phases of disruption

Figure 2 : International Maritime Supply Chain

Figure 3 : Potential Impacts of Port Disruption on MSC

List of Abbreviations & Acronyms

SC	Supply Chain
MTS	Maritime Transport System
SCRES	Supply Chain Resilience
SCRM	Supply Chain Risk Management
UNDRR	United Nations Office for Disaster Risk Reduction
WHO	World Health Organization
MSC	Maritime Supply Chain
IT	Information Technology
DCV	Dynamic Capability View
RBV	Resource Based View
OECD	The Organization for Economic Cooperation and Development
TEU	Twenty-foot Equivalent Unit

1. Introduction

The following chapter offers an overview of the contextual background concerning supply chain disruptions, as well as their impact. It is hereby showcased the durability of the shipping supply chain, along with ongoing research challenges, with the existence of practical and theoretical gaps in this domain necessitating further research efforts.

1.1 Background

Supply chains have grown to become an important part of global trade. A fairly new definition of the supply chain by (Ivanov, Dolgui, & Sokolov, 2019) describes a supply chain as a collaboration between numerous enterprises throughout all stages of the supply chain that work together in order to procure raw materials and turn them into finalized products that are delivered to end users.

Therefore, as per this particular interpretation (among numerous others), the supply chain commences at the procurement of unprocessed materials. With a supply chain that starts at the source of materials and ends at the customer's doorstep, it's clear that this process is particularly relevant in contemporary times. In modern times, manufacturing products is a challenging task that demands significant coordination effort, especially because products are now composed of more sophisticated components. The intricate nature of products is attributed to the countless parts and components they entail. This complexity ultimately contributes to the overall product's significant level of intricacy. The intricacies of supply chains have been extensively documented in literature (Closs, 2010). Several studies have been conducted on this topic, including (Eckstein, 2015), (Inman, 2014), and (Yazdani, 1999). The achievement of this intricate procedure, must be executed with utmost efficiency, prioritizing speed. (Palagyi, 2004) highlights the importance of minimizing customer wait times by streamlining the product delivery process. In this context, customers adopt a "better, cheaper, now" mindset.

In summary, one of the primary objectives of a supply chain is to meet demand. A fundamental purpose of a supply chain is to establish a reliable and efficient connection between vendors and clients, as emphasized by Ivanov, (Ivanov, Dolgui, & Sokolov, 2019). (Prokop, 2017) contributes an additional perspective to the matter; specifically, the "nodes" in a supply chain, which refers to the companies involved. The entities inside a supply chain,

along with their interconnections, create a complete system that holds more value than the mere total of its parts. As stated by (Prokop, 2017), nodes are integral parts of the supply chain. In other words, the supply chain is a complex network of interdependent components. An interconnected value network, valuable beyond the sum of its parts, stands in the form of a global supply. Global supply chains and local supply chains share a common purpose, however, the latter pertains to companies that operate on a international level. In addition to the global factor, there are various other elements that necessitate attention while managing. Engaging with international teams often involves cross-cultural negotiations and a higher degree of risk, particularly from an economic standpoint. All aspects of commerce, whether commercial or political, are intertwined with global supply chains. These supply chains can be affected by trade barriers, and legal disparities across different regions. Addressing situations necessitates a thorough evaluation of both transactional and transportation expenditures.

Imposition of further issues is possible with the addition of Rules of Origin, as stated by Eyob and Tetteh (Eyob, 2012) and (Prokop, 2017). (Ohmori, 2019) have presented their views on the arrangement of global supply chains, with a specific focus on rules of origin. Procedures were implemented to establish the "nationality" or origin country of a product. Significant in view of the levies imposed as a result of custom duties and other limitations (Ohmori, 2019). The push for globalization has led to a rise in global supply chains, as companies strive to expand their reach and gain a competitive edge. The distribution of market shares and the global trend towards embracing free trade as a principle of economic orientation. The supply side is affected by these factors. Over time, chains that were once basic connections between a few suppliers, or even just one, evolved into intricate networks. There are global networks that encircle the world, as noted by (Eyob, 2012). According to Tetteh (2012) global supply chains come with both advantages and disadvantages and while specialization can be beneficial, there are also potential dangers associated with it. Either a nation's economy or a company's financial outlook can be vulnerable to significant fluctuations stemming from changes in the global environment. The volatile and unpredictable nature of this phenomenon renders it highly probable, as per the research conducted by (Johnson G. W., 2017) in 2017 (p. 33) and (Mack, 2019). The advent of global supply chains has led to a number of concerns, including a rise in the practice of outsourcing. Supply chain executives typically make supplier selections based on various factors, such as the level of quality. The needs of customers are a key determinant of several factors, such

as quantity and price, among others. This, in turn, has a significant impact on the geographical aspects of the business. Adapting to shifting customer demands is crucial. Additionally, outsourcing frequently accompanies this process.

The concentration and integration of choices have been studied by (Ivanov, Dolgui, & Sokolov, 2019) and (Sindi, 2017).

To thrive in the current dynamic environment, a "one size fits all" approach is no longer adequate. Global supply chain strategies play a crucial role in decision-making, making the selection of the appropriate strategy a significant matter. The subject of global supply chains is explored in depth by (Christopher, Peck, & Towhill, 2004). Without proper execution, even a sound strategy amounts to nothing. This fact underscores the importance of execution for the group. The key decision-makers in any organization are the executives. It is crucial for them to align their actions with the overall strategy; otherwise, the consequences could be detrimental. A plan destined for failure is a likely outcome when a supply chain manager's choices are made without considering their direct impact. Financial performance of a company is significantly impacted by decision-making. Coordination is key in these matters. It's crucial to bear in mind that resources have financial implications, hence the importance of constant awareness.

When a company faces choices related to the supply chain, it must take into account its financial ambitions (Rosenberg, 2018). It goes without saying that this becomes exponentially more intricate and crucial when expanded in size. At a global scale, rather than solely within domestic or regional boundaries. Globalization has led to more complex supply chains (Shishodia, 2021) and for that reason The Marine Transport System (MTS) is an extremely important link in supply chain management, since about 90% of world trade is carried by sea (OECD). Disturbances from external factors, such as changes in consumption supply and demand have a significant impact on the industry (Berle, 2011) since they present obstacles that need be overcome.

As supply chains become more complex in an increasingly globalized economy, more resilient supply chains are needed to reduce risk and impacts of disruptions, as well as a chain reaction throughout the supply chain (Ponomarov, 2009). To manage these risks, Supply Chain Resilience (SCRES) acts as a supply chain risk management method. In the literature to date, attempts have been made to systematically conceptualize SCRES either via literature research ((Ali, 2017); (Hohenstein N. F., 2015); (Singh, 2019)) or bibliometric analysis (Shishodia, 2021). Definitions of SCRES typically include: different stages of

resilience, resilience strategies, and resilience skills (Ali, 2017). Ponomarov and Holcomb (Ponomarov, 2009) defined SCRES as “the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them [to the same or better state] by maintaining continuity of operations at the desired level of connectedness and control over structure and function”. The definition emphasizes that elasticity is an important function of the supply chain to prepare for disruption, reply, recover, learn and grow.

Supply Chain Risk Management (SCRM) is an essential part of risk mitigation.

That assists in maintaining efficient processes even in the face of disruptions. This includes identifying risks in the supply chain, assessing the consequences, deciding what action to take and acknowledge what impact a particular disruption might have on supply chain performance (Ho, 2015). By identifying and assessing potential risks throughout the supply chain, organizations can implement strategies to mitigate various risks (Manuj, 2008) categorized risks as environmental, cyber or organizational risks, where environmental risks are related to accidents or natural disasters, cyber-related risks and lack of response or changing market conditions and organizational risks that affect work, production or IT structure (Juttner, 2003)

1.1.1 Cases of Disruption

Disruptions to the supply chain can arise from various sources, including external factors such as natural calamities and factors within the organization, like breakdowns in the integration of specific supply chain functions. According to Ponomarov and Holcomb's study in 2009, disruptions can manifest as either a slow-onset or a sudden-onset event (Ponomarov, 2009). Van Wassenhove (2006) highlights that the gradual emergence of a disaster can be recognized through its appearance over time (Van Wassenhove, 2006).

Time is a crucial factor in categorizing epidemics as slow-onset disasters. Conversely, sudden-onset disasters have an immediate impact. Arising suddenly and without warning, rapid occurrences like failures in essential infrastructure or unexpected events. Considering that transport accidents are a major concern for the United Nations Office for Disaster Risk Reduction (UNDRR), it becomes imperative to delve into two distinct disruptions related to this issue.

Occurring incidents like COVID-19 and the Suez Canal blockage in 2021 could offer valuable insights regarding supply chain disruptions. To meet various challenges, the ability to adapt and persevere is necessary, particularly in situations involving complex chain disruptions. The SARS-CoV-2 virus is the culprit behind the global pandemic known as COVID-19, a respiratory illness. According to WHO, the first outbreak of the virus occurred in Wuhan, China, in December 2019 (WHO). The World Health Organization (WHO) reported the virus' worldwide reach. On March 11th, 2020, it was declared a global health emergency. The COVID-19 outbreak was officially declared a worldwide pandemic by the World Health Organization in 2020, as per WHO's announcement (WHO). COVID-19 has caused a distinctive form of gradual disturbance to global supply chains. Epidemics create disruptions on a global scale that tend to last for long periods. Simultaneous interruptions in supply and demand lead to high uncertainty, causing ripple effects across various industries. As per Ivanov's report in 2020, the pandemic outbreak of COVID-19 has caused an impact on both immediate and long-term logistical infrastructure (Ivanov, 2020). The effects of government regulations and resource scarcity are expected to have enduring consequences for maritime transportation. Scarce resources and sudden fluctuations in needs and availability have been noted in recent studies (Ivanov, 2020).

The year 2021 witnessed a decrease in demand, which was first observed during the implementation of lockdowns (Notteboom, 2021). The shuttering of manufacturing plants initiated in China and spread to Europe and North America. By decreasing the need for Chinese imports, widespread disruptions in global supply chains arose. The impact of epidemics on chains has been thoroughly explored in recent literature (Cullinane, 2021). Although the topic of humanitarian logistics has been extensively researched, there has been comparatively little investigation into the subject.

In 2021, the Suez Canal faced a blockage known as "Suez Canal blockage-21." A 400-meter container ship obstructed the bustling waterway, causing disruption and chaos. A sudden disturbance that had a direct and immediate impact on worldwide commerce. The six-day route disruption had far-reaching impacts, leading to delays around the world. The blockage of the Suez Canal was relieved just a few days later, however, the incident left a lasting impression on worldwide supply chains for a number of weeks to come. During the blockage, more than 300 ships were queued up, obstructing the transit of 12 percent of the world's trade through the Suez Canal (Dürr, 2021). According to Dürr (2021), the Suez Canal has the potential to disrupt global trade. This is evident from the backlog of ships that

have accumulated in the canal. Several commodities were subjected to penalties, causing a delay of almost \$15 billion to \$17 billion in that particular sector. With reference to LeBlanc (2021), the canal saw a constant influx of ships that had to queue up until their turn to pass through (LeBlanc, 2021). The resumption of traffic proved to be problematic as the backlog resulted in container and ship availability issues. The susceptibility of the waterway connecting Asia and Europe is largely dependent on the merchandise traversing through it. International measures have come to light in light of the recent Suez Canal disruption. Efforts have been made to explore substitute sea lanes (Lee, 2021).

1.1.2 Analyzing the issue

The effect that both the Suez Canal blockage-21 and COVID-19 had on supply chains has been substantial and with repercussions that are being visible in the long term. In these unprecedented times of lockdowns and volatile supply and demand, visibility has been significantly heightened. The reduction in demand poses a significant challenge for global trade, as highlighted by Kumar & Sharma's study in 2021 (Kumar, 2021) was quickly followed by a surge in commercial products, as noted by Alamoush and colleagues in their own 2021 research (Alamoush, 2021). The recent disruptions have taken a severe toll on stakeholders who are part of global MSCs, with many experiencing significant setbacks due to being stuck.

According to Notteboom et al. (2021), supply chain resilience is often challenged by unstable resources, unpredictable lead times, and fluctuating prices (Notteboom, 2021). This can be abbreviated as SCRES. The concept is still relatively fresh in the realm of supply chain management scholarship, with only a handful of frameworks currently available.

Conceptualizations for SCRES have been suggested by scholars such as (Christopher, Peck, & Towhill, 2004) and (Ponomarov, 2009) and have discussed this issue extensively. Despite this, it is worth noting that the vast majority of the global population remains unaware of it. Although the transportation of trade is facilitated by the MTS, the concept of resilience in the MSC remains fairly uncharted. As the COVID-19 pandemic continues to unfold, new findings have emerged from recent studies conducted by (Alamoush, 2021) and (Ho, 2015). Given the recent Suez Canal-21 blockade, it is crucial to emphasize the significance of effectively mitigating and handling risks and disruptions. The global reach of MSC is

undeniable, as evidenced by the congested ports and unprecedentedly high freight rates, as noted by Cullinane (Cullinane, 2021).

1.1.3 Purpose of this dissertation

This thesis delves into the analysis of supply chain resilience, emphasizing the demand for dynamism. Deploying operational competencies within the global marine transportation industry, in order to alleviate potential repercussions. Particular emphasis was given to susceptibilities exposed by both gradual and abrupt disturbances specifically by the repercussions of two major events: the COVID-19 pandemic and the blockage of the Suez Canal.

1.2 Literature Review

The subject of supply chain resilience is hereby introduced, with an emphasis on its theoretical underpinnings. To illuminate the topic, the focus will be on both the resilience of supply chains and the resilience of the maritime supply chain in particular. A thorough literature search has been conducted on this dissertation with emphasis both on older studies on resilience and on more recent studies concerning the effects of COVID-19 and the blockage of the Suez Canal. Comparative analysis of the findings from various authors has been conducted with an effort of discerning the elements of disruption and their effects on the maritime industry.

1.2.1 Managing Risks through Resilient Supply chains

In a more interconnected world economy, the complexity of supply chains is on the rise. In order to minimize the effects of disruptions, it is imperative to establish supply chains that are more robust and can withstand unforeseen events. According to (Ponomarov, 2009), there may be ripple effects across supply chains. To address this, measures should be taken to mitigate the potential consequences.

Supply chain resilience (SCRES) acts as a means of managing risks within the supply chain. Previous literature has made an attempt to define SCRES by utilizing a systematic approach.

According to Ponomarov and Holcomb's definition from 2009, SCRES (Supply Chain Resilience) is the capacity of a system to adapt to changing circumstances (Ponomarov, 2009). Establishing a robust supply chain is crucial to brace for unforeseen circumstances, effectively tackle disturbances, and regain stability in their aftermath, ensuring that they are brought to an equivalent or superior state by preserving the continuity of operations as required. The "level of connectedness and control over structure and function" concept, as per Ponomarov and Holcomb, refers to the degree of influence and authority over the organization's operations and framework (Ponomarov, 2009). Resilience is emphasized as a crucial capability of the supply chain.

A sequential chain of actions is necessary to brace for, react, recuperate, learn from, and emerge stronger in situations of upheaval. Risk mitigation is crucial, and supply chain risk management (SCRM) plays a vital role in achieving it. Smooth operations even in the face of disturbances require a strategy to pinpoint supply chain vulnerabilities. Evaluating the outcomes, determining the appropriate steps to be taken, and recognizing them. The study conducted by Ho et al. explores the potential effects of a disruption on the performance of supply chains, taking into account the complete supply chain, possible hazards are recognized and assessed (Ho, 2015).

Strategies can be adopted by organizations to minimize a range of potential risks. According to Jüttner et al. (2003) risks are categorised as either environmental, network or organizational risks, while environmental risks concern accidents or calamities, organizational risks pertain to potential hazards within a company's structure (Juttner, 2003). Supply chain protagonists may face network-related risks due to unresponsiveness amongst themselves. Organizational risks pertain to work, production, and IT, while market fluctuations impact conditions for change. According to Jüttner et al. (2003), issues within supply chain operations can arise from inadequate integration of specific functions in the structure (Juttner, 2003).

1.2.2 The susceptibility and interruptions of the supply chain

Supply chains that are more vulnerable are at a higher risk of being impacted by disruptions and the resulting consequences. As per the research conducted by Pettit et al. (2010), the repercussions of the disturbance are evidently more serious (Pettit T. J., 2010). The primary

goal of SCRES is to mitigate supply chain vulnerabilities, and as a result, mitigating the effects of disruption is crucial (Jüttner M. , 2011). However, when the impact of disruption exceeds a certain threshold, it creates an elevated level of risk. It's more likely to experience vulnerabilities that outweigh capabilities, or a decrease in profitability when capabilities are lacking. Investing in resilience can be expensive, making it more significant than vulnerabilities. Therefore, one should carefully consider the costs before making decisions. The need to balance vulnerabilities against capabilities for mitigating disruptions has been emphasized by Pettit et al. in 2013 (Pettit T. J., 2013). In a study conducted by Pettit et al. in 2010, it was found that vulnerability levels cannot always be directly associated with ensuring the durability of a supply chain and implementing risk-reducing measures may not always be synonymous (Pettit T. J., 2010).

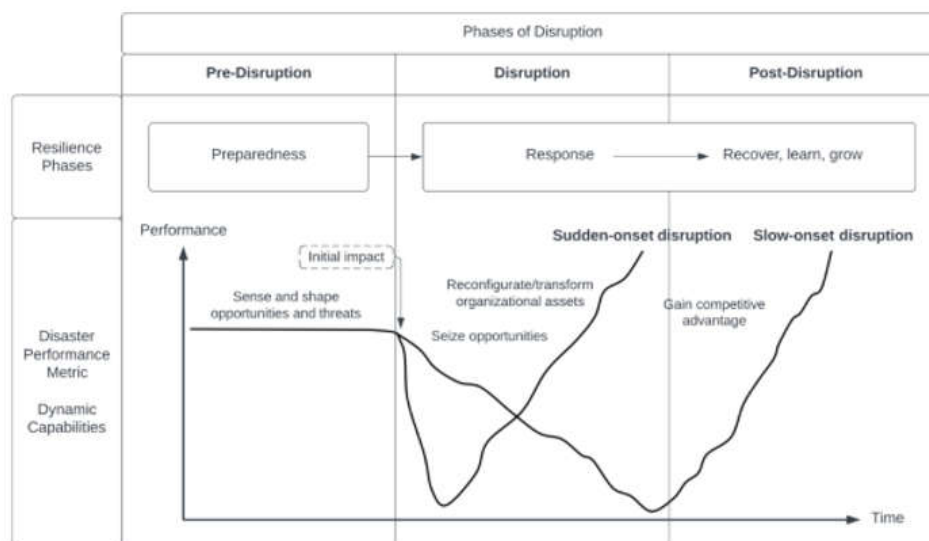
One way to enhance the supply chain's durability is to decrease its susceptibility and enhance its resilience. Minimizing exposure to specific regions can decrease the likelihood of disturbances but does not necessarily enhance the situation. The capacity of the supply chain to react and rebound from interruptions in order to prepare for potential disruptions, it is crucial for companies to determine which areas they are most susceptible (Jüttner M. , 2011). It is possible to estimate the likelihood of an event by utilizing historical or industrial data analysis. Planning for potential disasters is crucial, and scenario planning is an effective way to prepare (Manuj, 2008). It may be crucial to employ an alternative method to predict the effects of constantly changing risks. Preparing for management planning, decision-making, and building resilience is essential.

The identification of vulnerable points can be achieved through various techniques, including simulated testing, as highlighted by Sheffi and Rice in 2005 (Sheffi, 2005). There are various classifications for supply chain disruptions, particularly in the humanitarian field. Van Wassenhove's (2006) classification categorizes disturbances based on their origin, distinguishing between those caused by human activity and those resulting from natural calamities (Van Wassenhove, 2006).

A disturbance in supply can occur either suddenly or gradually. In the event of a sudden disruption, the impact on the supply is immediate. Disruption can arise from a range of causes, including natural disasters or those triggered by human actions, such as acts of terrorism. Sudden attacks cause immediate impact while disturbances with a gradual onset gradually affect the supply.

In instances of either famine or political turmoil, as noted by Van Wassenhove (Van Wassenhove, 2006). The occurrence of disruptions can be categorized into three distinct phases: the pre-disruption phase, the disruption phase, and the post-disruption phase. The term "pre-disruption" refers to the period before a catastrophic event occurs, where a strong and durable plan can be put in place to mitigate the effects of the disaster. Incorporating the capacity to predict (as noted by Shishodia et al., 2021), plan for, withstand, and circumvent (Shishodia, 2021). The occurrence of a disaster can bring about disruptions (Ali, 2017). It is during the disruption phase that the disaster hits. Effective tactics encompass opposing (Shishodia, 2021), reacting, enduring, and the 2017 study by Ali et al. (Ali, 2017) emphasizes the importance of adjusting to new circumstances, and ultimately culminates in the post-disruption phase. In the aftermath of the disturbance, approaches to address the situation, such as recovery, survival, and response tactics, were explored (Ali, 2017). According to Shishodia et al. in 2021, the capacity to learn and expand is outlined (Shishodia, 2021). Reconstructing the supply chain by focusing on growth is crucial in enhancing preparedness. The phenomenon of potential disruptions to come has been dubbed the "disaster cycle" in the field of humanitarian logistics. SCRES encompasses five distinct phases that can be broadly categorized as: preparation, reaction, and recuperation (Ponomarov, 2009), learning (Tukamuhabwa, 2015) and growth (Hohenstein N. F., 2015).

Figure 1: Supply chain resilience through the phases of disruption



Note: Own construction

A supply chain that can withstand disruptions is the hallmark of resilience, despite the fact that SCRES encompasses various factors that are widely accepted. On the other hand, it is essential to note that Hohenstein et al. (2015) emphasized the significance of possessing the aptitude to handle various stages of disturbance (Hohenstein N. F., 2015). The conceptualization of the capabilities that furnish SCRES has been somewhat lacking. Various scholars have referred to "unconstructed" using distinct vocabulary (Ali, 2017) (Hohenstein N. F., 2015). Various sources have highlighted indicators (Hollnagel, 2011) (Singh, 2019) and principles (Christopher, Peck, & Towhill, 2004) to be taken into consideration. Scholarly works from (Ponomarov, 2009), (Ali, 2017) and (Hohenstein N. F., 2015) among others, have explored different aspects of elements in their research. Zavala-Alcívar and colleagues (Zavala-Alcívar, 2020) focused on capacities, while Brusset and Teller (Brusset, 2017) delved into capabilities. In this thesis, SCRES's contributing factors will be thoroughly examined, as previously studied by Pettit et al. in 2010 (Pettit T. J., 2010). Described as capacities, these abilities can exist on either an operational or dynamic level.

1.2.3 Dynamic and Operational Capabilities

The performance of the supply chain throughout every stage is intricately tied to its dynamic capabilities. The concept of resilience has been explored in recent studies (Kähkönen, 2021) (Singh, 2019) particularly in connection with the dynamic capability view (DCV). Higher-level activities and routines, which are crucial for organizational functioning, are encompassed in DCV. Deliver enduring efficacy and gain a competitive edge in a swiftly evolving landscape. Numerous studies have highlighted the significance of environments (Hassan, 2017) (Kähkönen, 2021) (Teece, 2007), as a critical factor that needs consideration in order to ensure longevity in terms of performance and adaptability in fast altering environments. The DCV serves as a continuation of the resource-based view.

The main focus of RBV (Resource-Based View) is on the utilization of current resources, as pointed out by Chari et al. in 2022 (Chari, 2022). To possess dynamic capabilities, one must possess the capacity to comprehend their surroundings and accurately perceive them. To capitalize on opportunities and mitigate threats, it is essential to shape them in your favor and take necessary action. As outlined by Teece (2007) (Teece, 2007) and Kähkönen et al.

(2021) (Kähkönen, 2021), it is imperative to restructure and convert resources within an organization.

Operational capabilities refer to fundamental organizational tasks that serve to improve its functioning. Enhance business processes by streamlining operations, focusing on cost reduction and boosting efficiency. Maintaining a significant link necessitates resilience, as stated by Hassan et al. in their 2017 study on quality (Hassan, 2017). The association between long-term competitive advantage and dynamic capabilities has been highlighted by Ponomarov et al in their 2009 study (Ponomarov, 2009). The concept of resilience necessitates that organizations possess the capacity to both plan ahead and react effectively. According to Ali et al. (2017) (Ali, 2017) and Hohenstein et al. (Hohenstein N. F., 2015), one can develop resilience by adapting, recovering, learning, and growing from a disturbance.

In previous studies (Jüttner M. , 2011) (Tukamuhabwa, 2015) conducted in 2015, it was discovered that "The capacity for expansion creates enduring benefits," as Tukamuhabwa puts it, suggesting that sustainable competitive advantages are a result of growth. While previous research has touched upon the subject, there's a critical lack of distinction between the operational aspects within SCRES literature. In fast-changing environments, resilience plays a crucial role in granting a competitive edge, enhancing the ability to withstand and recover from adverse situations. Previous literature has highlighted flexibility as a crucial aspect of successful capabilities. The list comprises of digital transformation factors like agility, velocity, visibility, design and reengineering, collaboration, and coordination. Agility encompasses several key factors. These include transformation, knowledge, experience, and robustness. The capability to promptly address unforeseen requests, thus minimizing exposure to vulnerabilities. The hazards brought about by extended response times (Christopher, Peck, & Towhill, 2004) demand attention. Flexibility, velocity, and visibility are crucial components of a robust supply chain. Several scholarly works on the topic include publications by (Christopher, Peck, & Towhill, 2004) (Ivanov, Dolgui, & Sokolov, 2019), and (Jüttner M. , 2011) Flexibility holds great significance as stated by (Pettit T. J., 2010) and (Zavala-Alcívar, 2020).

In a study conducted in 2019, it was established that velocity, which encompasses the ability to adapt to changes, and visibility, are two important factors to consider. Strong collaboration and seamless coordination among various stakeholders within the network.

Taking into account the viewpoint of both (Christopher, Peck, & Towhill, 2004) and (Scholten, 2015), as well as a network perspective, it can be concluded that in order to contain the ripple effect that permeates the supply chain, it became necessary to take action. The incorporation of digital technology plays a crucial role in reducing risk and enhancing resilience. Digitalization has transformed the supply chain landscape with the potential to improve visibility through big data analytics.

According to Ivanov et al. (2019) (Ivanov, Dolgui, & Sokolov, 2019), cross-channel coordination can become problematic. To improve this, it is suggested to comprehend the network and pinpointing areas of limited capacity.. According to Christopher and Peck (2004) (Christopher, Peck, & Towhill, 2004), there are bottlenecks that exist which affect the design of supply. The resilience of a chain is significantly influenced by its structure. As with any design, there are certain trade-offs that come with it. The contention arises between efficiency and redundancy, and between cost and excess capacity.

2. The worldwide shipping network

An intricate web of interdependent operations characterizes a worldwide maritime supply chain (MSC). This refers to the management of container transportation processes including the preparation, organization, and supervision of shipping operations where Lam (2011) notes that transportation of goods from their point of origin to their intended destination accounts for approximately 90 percent of international commerce. (Lam J. S., Patterns of maritime supply chains: slot capacity analysis, 2011)

As per OECD's records, global trade is a significant contributor. Unlike maritime conveyance systems, carriers and shippers play a vital role in this regard (OECD). MSCs establish customer-supplier relationships that vertically link ports within them. The selection process is conducted by stakeholders, who comprise carriers, ports, freight forwarders, suppliers, and others involved in the process. Numerous factors have played a pivotal role in molding the present state of global shipping containerization. The surge in commerce, emergence of fresh markets, and development of novel opportunities all

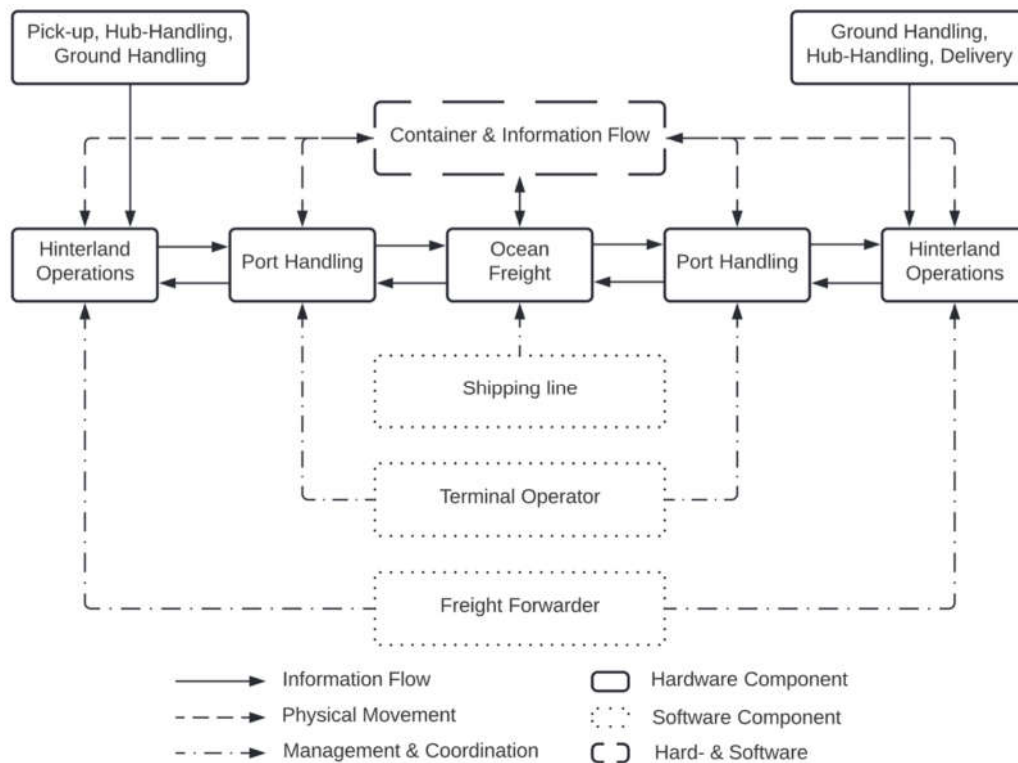
contributed to this growth. The intricate nature of supply chain logistics has been compounded by transport companies, contributing to the growth in trade difficulties.

With the rise of markets and economic expansion, the need for container shipments surged. According to Brooks and Cullinane's research in 2006, significant financial investment is necessary for sustained expertise in supply chain management (Brooks, 2006). Together with the integration of multi-modal infrastructure with investments culminated in a groundbreaking transformation of the maritime sector. According to Brooks and Cullinane (2006), the maritime industry benefits from the advantages of larger vessel sizes due to economies of scale (Brooks, 2006).

As technology progresses, shipping companies are adjusting to keep up with the changes and ensure smooth operations. The present-day approach to planning for the future of the market involves aligning development strategies with their vision. This often involves the utilization of extensive resources. Since 2011, the container vessel size has undergone significant development and is currently at its largest. There has been a significant increase in TEU, from 5500 in 1995 to over 23,000 in 2019, and beyond. These developments can be attributed to commercial reasons. The possibility of further expansion of vessel capacity relies heavily on existing and forthcoming container dimensions. The dynamics of the shipping industry are influenced by various market factors, including the flexibility of ports and their terminal capacity.

In both financial and technological spheres, while also factoring in environmental limitations and restrictions, Intermodal logistics have advanced with the gradual integration of ports. According to Liu's research in 2011, the transformation of supply chains into a multimodal global system can be visualized in Figure # 2 (Liu, 2011).

Figure 2: International Maritime Supply Chain



Source: Liu, 2011, p. 400.

2.1 Port Operators

As an essential component of international transport networks, ports are recognized for being not only a self-sufficient and integral space for transferring physical cargo but a systematic link in a multimodal logistics supply chain. Within this system, their role in coordinating the flow of materials and information makes the ports' role extremely crucial (Liu, 2011). Keeping costs to a minimum and ensuring reliable freight handling are emerging as important components of global transportation logistics and supply chain management. Evermore discerning customers are putting pressure on service providers to offer fast, just-in-time services at competitive rates (Liu, 2011). As a result, shipping companies may need to move their cargoes on a far more flexible timeline and require additional ports to accommodate them. Thus, the performance of logistics operators relies heavily on the efficiency of ports, which act as integration and coordination nodes across

the various components (Bichou, 2004). Integration refers to the degree to which stakeholders work together cooperatively and collaboratively to obtain win-win solutions, collectively referred to as the 'optimal solution' (Carbone, 2003). Companies have for several years focused primarily on cost when choosing suppliers, setting up factories, and determining inventory levels. Just-in-time production originated in Japan in the late 1940s to reduce inventory, shorten setup times, and lower costs in various other areas of the supply chain. Just-in-time cost reduction and efficiency improvement gained worldwide recognition and was subsequently incorporated by many companies. It has been argued that the primary risk and vulnerability of this strategy is over-dependence on supplier resilience and flexibility (Jiang, 2022).

In contrast to the just-in-time strategy that has prevailed in recent decades, (Jiang, 2022) argue for the just-in-case supply chain strategy to increase resilience for multinational organisations. The just-incase strategy suggests keeping larger inventories on hand to enhance greater robustness of the supply chain to major shocks and accounts for uncertainties where the worst case of a series of outcomes is optimized (Jiang, 2022). In theory, larger vessels allow ship carriers to perform better on unit costs due to economies of scale, while in reality, larger capacity vessels face ancillary constraints. Larger vessels are often more difficult to operate because they have greater demands on financial assets, time, and physical constraints, such as navigation channels in rivers and canals, berthing depths in ports, and transshipment terminals. The optimal vessel size should therefore be determined not only by the operational cost of the vessel but also by the negative external effects that the physical scale of the ship might exert on other logistics supply chain elements (Jansson, 1982). Often, ships that are larger typically have a greater water draft and are constrained by the physical limitations of port conditions. To a large extent, this accounts for why operators of high seas vessels frequently exert considerable pressure on port operators to enhance their infrastructures to reap economic advantages from the use of larger vessels (Heaver, 2020); (Notteboom, 2021). Liu (2011) argues that the seamless flow of cargo throughout supply chains is largely contingent on the ability of ports to function as effective hubs among vessels and other modes of transport, with their effectiveness and capacity being critical to the degree of the maritime logistics system optimization. In turn, this requires modern ports capabilities to be competitive and customer-focused in management and operations (Liu, 2011).

2.2 Maritime Shipping Companies

To enhance the transportation supply chain, the inclusion of shipping companies can be viewed as an effective measure. A crucial approach to fulfilling demands while ensuring the survival of companies involves strategic planning. The current scenario is highly competitive. The growth of seaborne trade in the past few decades reflects this trend.

As markets continue to converge globally, a distinct geographical contrast in both supply and demand remains prevalent. The surge in global demand for freight services has raised expectations accordingly. One of the biggest challenges to date has been the transportation of maritime cargo. However, this challenge extends beyond mere completion. Not only have shippers and recipients become more demanding, but the level of demand has also increased. Demanding better standards of transportation services, cargo customers expect excellence in the service provided. Shipping companies require quick and reliable transportation services offering cost-effective pricing and having a wide geographical hile consistently strive to expand their network for better accessibility. Shipping companies can expand their operations either by organic growth or by merging with other companies. The fulfillment of expectations and demands, as noted by Panayides et al., is a primary objective behind acquisitions (Panayides, 2012). The primary goal of a MSC is to create additional value for the goods being transported. By providing spatial and temporal value, a MSC facilitates the transportation of goods to and from various locations. The origin of the cargo values it less than the destination it is headed to.

Shipping companies are responsible for managing the transportation of goods at a superior level within the supply chain, facilitate the flow of freight, information, and financial transactions across the entire supply chain. Working in tandem with a variety of invested parties, such as carriers and ports, has been noted by Lam (Lam J. S., 2015).

2.3 Freight Forwarders

The task of organizing transportation is carried out by a freight forwarder in collaboration with various carriers (Skiba, 2022). It is their responsibility to ensure the secure conveyance of entrusted merchandise.

The emergence of freight forwarding is intertwined with the expansion of goods production. Trade and transportation have both undergone significant evolution. Demand for these services arises from the purchaser's need to outsource their commodities transport operation in contemporary times, it is uncommon for buyers to personally oversee the transportation of their merchandise. In the present day, freight transportation is handled by specialized companies as opposed to being the responsibility of the sender or recipient.

Active participants in the transportation network, forwarders are primarily involved in the movement of goods. The transportation of goods involves a variety of all-encompassing tasks, known as freight forwarding. In addition, a freight forwarder acts as a mediator working on behalf of importers. Entities that require secure and efficient transportation arrangements can delegate the responsibility to exporters or appointed representatives. A professional who operates within economical parameters and facilitates maritime transportation is known as a maritime freight forwarder. Proficient in precise coordination of transportation services and adeptly resolving any unforeseen issues that may arise. The forwarder often considers the planning phase of the transportation chain.

One of the critical concerns is finding the right approach to work together with stakeholders in the supply chain. Without a doubt, it is of utmost importance that the forwarder possesses the ability to sway and bargain with others. Multiple participants within the MSC work collaboratively to attain the highest possible value for the ultimate consumer. To streamline the shipment process, the freight forwarder outsources subsequent tasks to other entities. Collaborative entities such as partners, subcontractors, or other carriers that offer complementary services (Skiba, 2022).

2.4 Land Transportation

The scope of land operations comprises the intermodal transportation lines that link ports to inland destinations. (Van Der Horst, 2008). Numerous private enterprises partake in the development of inland regions. Entities involved in transportation, including shipping companies, terminal operators, freight forwarders, and the hinterland. Furthermore, there are several inland terminal operators and transportation providers, along with multiple public options available. Various stakeholders including port authorities, customs officials, and infrastructure providers have been actively involved.

The transportation of containers has emerged as the primary mode of cargo shipment in several ports and a significant aspect of the process. The intended destination for the transport flows from these ports is the nearby hinterland. Ports have a significant interest in ensuring access to their hinterlands. This makes the relationship between ports and their surrounding areas a crucial aspect to consider. Incremental container volumes can only be accommodated and managed by transportation networks if efficient and effective management characterizes the transportation system in the hinterland. Moreover, dry ports possess the potential to serve as a central point for intermodal transportation, these hubs are typically linked to seaports via rail. In order to alleviate congestion, terminals often opt for the use of these as a substitute for storing goods. Goods can be received both from trucks transporting them to the port and within the terminal itself (Khaslavskaya, 2019) (Russell, 2020).

2.5 Building Resilience in the Maritime Supply Chain

Existing literature largely concentrates on the broader aspects of the concept of SCRES, which is still a relatively new idea. The durability of the MTS has yet to be extensively examined, as opposed to the worldwide supply chain. The geographical region has been a topic of discussion in Lam's 2012 and Russell et al.'s 2020 studies (Lam J. S., Risk Management in Maritime Logistics and Supply Chains., 2012) (Russell, 2020). The ongoing fluctuations in worldwide commerce contribute to escalating ambiguities. The interconnections among distinct nodes and entities in transport systems are crucial.

Recognizing the significance of durable transportation infrastructure in furnishing dependable and (Berle, 2011) and (Wan, 2018) have emphasized the importance of effective supply chains. This includes transportation resilience as a key factor. The capacity to absorb disruptions and endure stability in a transportation system is commonly referred to as "resilience." To restore its necessary level of service, recuperation to the mandated standard from any malfunction is imperative in regards to the fundamental construction and operation of the system. According to Wan et al. (Wan, 2018), the ability to recuperate from disruption while keeping costs and time at a reasonable level is considered acceptable. Compared to other transportation systems, MTS boasts a greater number of interfaces that offer nodes that are potentially vulnerable are a consequence of industry consolidation and a surge in

the association between regulations was emphasized in studies conducted by (Berle, 2011) and Lam (Lam J. S., Risk Management in Maritime Logistics and Supply Chains., 2012). A comprehensive outlook is necessary when dealing with distinct performers in the MTS, as per Lam's findings in 2012. Earlier scholarly works on the subject of SCRES in the MTS tend to concentrate solely on an individual participant. As a critical component of an extensive supply chain, the MTS plays a significant role in the provision of supplies. According to Berle et al. (Berle, 2011), disturbances in the MTS can potentially trigger a domino effect on the entire network.

As far as maritime supply chains (MSCs) are concerned, disruptions refer to any incident or circumstance that a sudden disruption in the normal flow of goods through a supply chain can cause a complete cessation of operations. The transportation of goods is constantly in motion, but it also poses potential hazards to companies through operational and financial risks. The effects of disrupting a specific link in the supply chain reverberate beyond its immediate impact, causing indirect consequences. The impact of disturbances on transportation reverberates throughout the entire supply chain network.

Failures within the maritime supply chain can be attributed to various actors, resulting in a breakdown of the system. For instance, the disturbance at one port could lead to setbacks for ships reaching a different port. The amplification of both immediate and consequential outcomes is on the rise, as stated by Asadabadi & Miller-Hooks in 2020 (Asadabadi, 2020). If the ability to supply is weak or the financial state is unstable, disruption can ensue. Transparency in coordination has the potential to augment the flexibility of MSCs. Information that is up-to-date and can be accessed immediately through tracking and tracing tools, big data, or other digitalization methods.

2.5.1 Port Handling

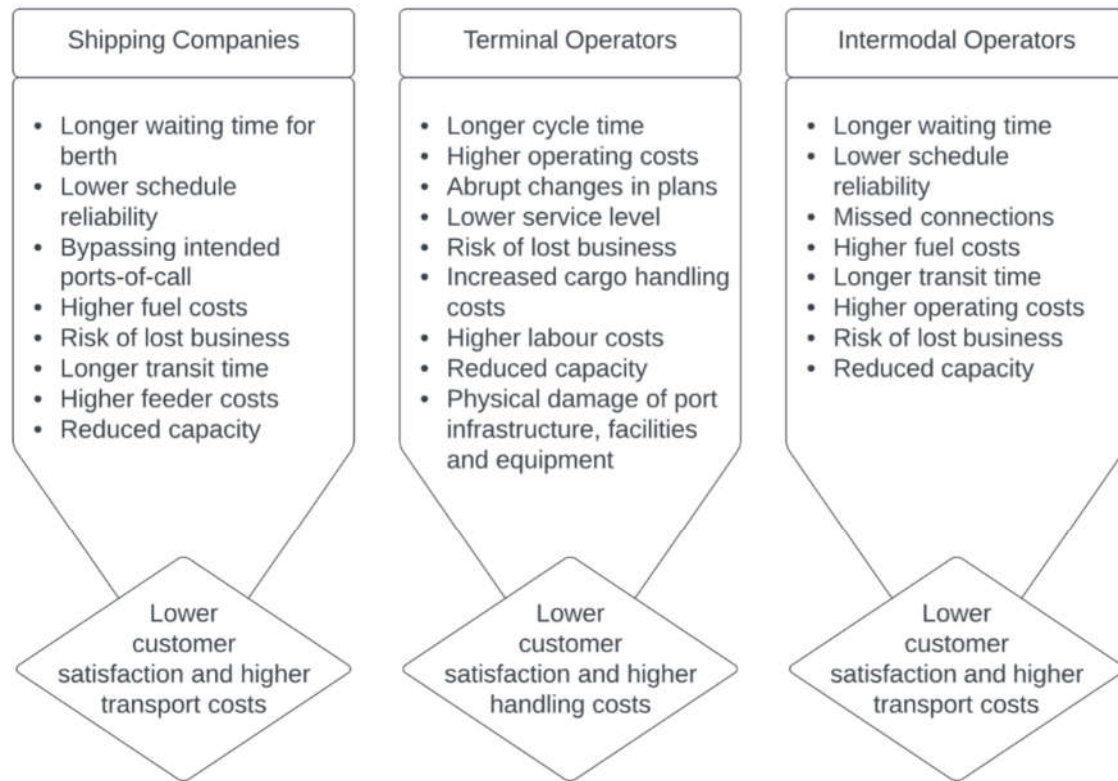
According to earlier studies, ports are regarded as key players in the MSC (Liu, 2011). The operational difficulties of containerized trade have been brought to light due to its surge in popularity, as highlighted by Russell and colleagues in 2020 (Russell, 2020). New market dynamics and innovative supply chain strategies have emerged, particularly for ports operating in the global maritime trade.

The quality of service and physical manipulation of containers are closely linked. The handling of containers, in particular, can be uncertain. As the number of ports grows, the

significance of their adaptability is becoming progressively more crucial (Russell, 2020). The significance of resilience in ports cannot be overstated. This is because any disturbance in port operations could have far-reaching consequences. The potential impacts of port disruption in MSC as shown in Figure 3, justify the need of the industry to increase its resilience. The term 'port resilience' is defined as the capacity to a port's ability to recuperate and return to a stable state following a significant event is dependent on its speed and recovery period. According to Jiang (Jiang, 2022), the concept of "disturbance" is a significant consideration. To achieve operational flexibility, potential practices may be implemented. The handling of equipment in ports is highly adaptable, with alternative transportation modes and enhanced flexibility.

To establish enough buffer capacity, Russell et al. (2020) (Russell, 2020) suggest that a storage area is necessary for ports. In addition, a port requires being agile and robustness is crucial when it comes to tackling unforeseen disruptions and mitigating declines. It is important to respond quickly in order to minimize any negative impact. The movement of cargo via ports, and the subsequent decrease in revenues, has been highlighted by Lam (2012) (Lam J. S., Risk Management in Maritime Logistics and Supply Chains., 2012) and Russell et al. (2020) (Russell, 2020).

Figure 3: Potential Impacts of Port Disruption on MSC



Note: Own Construction

The pandemic's effect on container volume was unmistakably evident in seaports. Prior research conducted by Alamoush et al. (Alamoush, 2021) and Notteboom et al. (Notteboom, 2021) provides evidence that owing to the initial onset of the pandemic resulted in limited demand and high inventory expenses, importers were compelled to abdicate cargo responsibility which led to a significant amount of inventory remaining unattended. As posited by Notteboom et al. (Notteboom, 2021), terminal yards bore the brunt of the pandemic's impact. Yet, as demand re-surged, the situation began to change. The significant restocking efforts resulted in an immediate surge in port demand. Port arrivals have been subject to medical checks, personnel infected with diseases, and quarantines, leading to challenges faced by dock workers. The outcome of this situation caused a slowdown in progress and increased traffic.

Due to rising demand, the extended processing time required for bigger vessels was addressed in 2021. As per the research conducted by Cullinane and Haralambides in 2021, ports are facing persistent pressure (Cullinane, 2021).

To manage the surge of freight and avoid unwanted outcomes, it is crucial to possess adequate capabilities. Preparation and risk mitigation are crucial in preventing supply chain disruptions caused by congestion, which can have ripple effects throughout the entire system. To enhance their operations, terminal operators must prioritize mitigation as a vital factor. Lam (2012) (Lam J. S., Risk Management in Maritime Logistics and Supply Chains., 2012) emphasized competitiveness, but according to Notteboom et al. (Notteboom, 2021), cooperation is equally important. Achieving harmonious collaboration among parties involved and implementing economic measures to offset losses in port operations is a prerequisite for global trade and all parties involved in the Maritime Supply Chain.

2.5.2 Land Operations

An agile port is of utmost importance not only for port operators, but also for carriers and logistics operators. Terminal services are offered by maritime transportation service providers with limited operations. As noted by Russell et al. (Russell, 2020), an increase in capacity could lead to congestion extending beyond the port itself. This highlights the potential for growth-related issues that must be considered. The advent of containerized transport has led to a rise in insufficient space capacity. Hossain et al. (Hossain, 2020) emphasize the significance of expeditiously transporting cargo from ports, highlighting a shortfall in this area.

The outbreak of COVID-19 sparked capacity issues in hinterland transportation due to a shortage of truck drivers. To minimize risk in 2021, one viable approach is to implement the use of dry ports, which can effectively alleviate congestion within the area. Russell et al. (Russell, 2020) proposed an alternative to truck transportation, aiming to alleviate port terminals' congestion. Dry ports serve as a dependable and sturdy substitute for transporting cargo out of a particular location.

2.5.3 Ocean Freight

The smooth functioning of maritime supply chain is crucial. Any disturbance can have profound effects on both shipping and port operations. This can necessitate the implementation of new strategies to mitigate such disruptions. According to Notteboom et

al.'s research in 2021, alterations in market structures and business strategies can lead to delays (Notteboom, 2021).

The operational processes of vessels such as arrival, loading, and unloading can cause disturbances in ports. The presence of enough empty containers in a port is largely reliant on the carriers and their actions. The need for customers to return containers to ports often results in an imbalanced availability of containers. Carriers have the option of boosting their flexibility through the enlargement of their container fleets in various regions. To maximize container utilization, a sound plan is needed that includes renting out containers. As the environment undergoes change, the need for greater adaptability is a necessity.

With the rise of COVID-19, vessel management strategies have evolved. These include avoiding shared containers and maintaining a fixed order to minimize exposure risks.

In the book by Notteboom et al. (2021), blank sailings are utilized- which refers to the cancellation of certain parts of a voyage (Notteboom, 2021). To minimize the number of cancelled departures, there are several strategies employed along the route. Authors Alamouch et al. (2021) (Alamouch, 2021), Cullinane & Haralambides (2021) (Cullinane, 2021), and Notteboom et al. (Notteboom, 2021) all discuss the concept of capacity.

In the year 2021, a trade-off occurred where the service quality and vessel capacity were reduced, but in turn, it led to an increase in another aspect. Alamouch et al. (2021) (Alamouch, 2021) highlighted delivery delays caused by the rise in demand, which led to blank sailings being implemented. The effects of Covid-19 resulted in decreased wages and raised transportation costs. Analyzing literature reveals that this pandemic's primary aftermath was mostly due to the impact of governmental regulations that was significant on freight forwarders and shipping agencies. Stringent protocols, isolation mandates, and rigorous safety regulations coupled with limited capacity in the hinterlands. Due to issues with transportation, there were delays in the delivery of cargo, a decrease in demand volume, and other related problems. In order to lessen the quantity of financial concerns faced by patrons, as stated by Alamouch et al. (2021) (Alamouch, 2021), measures can be taken. The advent of cancellations led to the establishment of new services and ingenious storage solutions. This feature permitted clients to modify the shipment schedule without scrapping their order.

According to Lam (2012) (Lam J. S., Risk Management in Maritime Logistics and Supply Chains., 2012), an active risk management approach can greatly benefit the maritime industry. By enhancing the supply chain's readiness and minimizing its susceptibility to

interruptions, it's expected to deliver, as documented in the literature on SCRES, an enhancement the supply chain's capability to gain a competitive edge making it a common objective. Merely being prepared is insufficient for gaining a competitive edge. To gain an edge, the MSC must additionally increase their strategic planning agility. As Mohammed and colleagues (2021) (Mohammed, 2021) have highlighted, there are abilities within that can be harnessed to adapt and thrive. This is a crucial consideration given the current context. Given the interdependence among the various players in the MSC, it is apparent that simply to build a resilient strategy, is not enough. Instead, a thorough investigation and incorporation of multiple strategies are necessary.

3. Risks Associated with Disruptions in Supply Chain

In the upcoming chapters, we will briefly delve into the specific dangers related to the aforementioned risk proposal. The objective is to illustrate how the risks associated with each category can materialize through the use of visual representation. The categorization of risks involved in the supply chain, as per (Jüttner U. , 2005) is found in three categories, those of the supply-side, the demand-side and the environmental risks. Adding to the above categorization, Manuj and Mentzer (Manuj, 2008) included the operations/ operational risk, all of which will be discussed in the upcoming chapter.

3.1 Supply- Side Risks

Supply-side risks are those risks that originate in the upstream part in the supply chain meaning it is supplier oriented (Manuj, 2008). Upstream includes everything that happens in the supply chain before it comes into intended site/ location of the company - supply of raw materials, sub-components, etc. Possible supply-side risks include supply lead time (Glock, 2013), poor quality (Barroso, 2011), delivery delays (Talluri, 2006), lack or uncertainty of deliveries or no deliveries at all (Barroso, 2011), logistics or transport issues (Er Kara, 2017), geographical issues (Chan, 2007), any type of supplier failure (Ravindran, 2010), financial issues (Lockamy, 2010), even supplier bankruptcy (Handfield, 2008). That is Not an exhaustive list, just a small subset of what is suggested in the literature and well

represented various supply-side risks that a company may face. Material bottlenecks in particular are identified as one of the biggest supply-side risks. Raw material shortages according to DHL Resilience360 Annual Risk Report 2018 Top 10 Risks of Supply Chain. However, there is a trend towards regional production. When it comes to the final product, many components still come from all over the world. So a component like this prone to disruptions, such as demand surges or production bottlenecks. As example material Lithium-ion batteries used in the manufacture of products such as mobile phones or electronic devices are dealing with enormous disruptions resulting in lithium demand to increase dramatically in the coming years. Another important battery material (cobalt) is mainly mined in Congo, where instability is widespread. This risk is undercut by the fact that some companies that usually buy off-the-shelf batteries from the manufacturer started to buy the cobalt themselves (Kamal, The top 10 supply chain risks of 2019, 2019). Supply risks can also be asserted by the focus companies themselves. Delivery time risk arises when businesses underestimate how much material they need, but replenishment orders are not on a timely placement schedule. Especially for less common components or materials, lead times can be long. This exacerbates the consequences of underestimating demand (Jian, 2015). Additionally, environmental issues may have an impact In all parts of the supply chain, i.e. also on the supply side (e.g. cobalt issue). Another example is a consumer goods company facing customs strikes in countries where the company has manufacturing plants. Plants should have their needed raw materials in stock for three weeks of production, but only enough for one week is on its way to the plant. The factory had to stop production a week later due to a customs strike. In such individual cases, fixed costs and labor costs still have to be paid. As a result, factories producing the same goods lack the capacity to pack them. This makes it impossible to replace decommissioned plants. After the strike, the company investing in overtime production to catch up, resulting in very little actual shipments. Production was delayed for days. Nonetheless, the cost of this disruption totaled about one billion (Schmitt, 2012). In particular, supply-side risk cannot usually be directly reduced by mitigating the corresponding source of risk in hand . Therefore, companies must pay attention and have a diverse supplier portfolio and work closely with several reliable suppliers in order to build a solid foundation for a well-functioning supply chain .To achieve this, the supply chain need to be viewed as a strategic asset requiring careful planning and development of multiple risk mitigation strategies and contingency plans.

3.2 Demand – side Risks

In contrast to supply-side risks, demand-side risks occur downstream in the supply chain and are directed towards customers and are caused by possible risks that affect the end customer. Uncertainties in demand levels, as noted by Manuj and Mentzer, represent a significant source of demand-side risks (Manuj, 2008). Demand predictions can often vary substantially from the actual supplier demand and the discrepancy between prediction and reality in the consumer need can cause immense misalignment in the supply with substantial aftereffects to the firm with a major one being loss of income from lost sales. If businesses fail to align their chain strategy with their customers' requirements, there can be dire consequences. In such cases, on the one hand, if a company's strategy doesn't cater to its customers' needs, it can face significant backlash due to loss of opportunity. In the event that a company overestimates demand and stocks a surplus of products beyond the actual demand, it could potentially lead to residual stock that would potentially need to be scrapped or sold at a much lower price. If the stock is in short supply, the company may not meet demand, while an oversupply may lead to a discounted sale. According to Jian et al. (Jian, 2015), failure to meet customer demand can lead to lost revenue opportunities and financial setbacks.

Insufficient communication with clients can, at times, result in incorrect prognostications (Diabat, 2012). A company's deficient planning and untimely product launches can cause an adverse impact. Failure to identify market opportunities can result in missed chances and the need to write-off residual stock. In addition, demand volatility may also play a role.

Seasonal patterns or momentary trends can additionally prompt abbreviated product life cycles or any similar outcome. The aftermath of exaggerated responses or misinformation (commonly known as "fake news") can trigger confusion and disorder. Sources including (Johnson M. E., 2001) and (Jüttner U., 2005) have referred to the phenomenon as panic reactions or the bullwhip effect, a situation in which distorted demand occurs. Excessive stocking often results from a lack of coordination along the supply chain. Consider a situation where demand forecasts indicate a lower need for stock, yet multiple parties in the supply chain continue to maintain higher levels of inventory. The number of end-customers seems to be mostly accurate, if not a little inflated. However, every entity upstream should be taken into consideration.

In the supply chain, it is commonly assumed to incorporate a minor "safety buffer", an overestimation of figures before finalizing them. The production firm is not meeting the customers' demand due to a shortfall in production caused by some unknown factor. According to Li et al. (Li, 2017), the acquisition is expected to be completed in due course. In addition to the company itself, its logistics collaborators and retail partners are also involved in the process. Alongside customers, competitors can pose a significant threat to demand-side risks for any product. The introduction of a new product can cause considerable challenges. According to Manuj and Mentzer (Manuj, 2008) the act of competitors introducing themselves can cause fluctuations in demand. In addition to the volume of requests, the distribution of products is also susceptible to risk. This holds true for the supply side too, specifically in the area of transportation and distribution, where risks abound.

The interconnectedness of modern commerce means that a single disruption to the network can have far-reaching effects. Consider the impact of a truck driver strike, which could render a company unable to fulfill delivery obligations. Delivering products to clients or vendors can lead to financial losses and damage to reputation. Producers are greatly concerned about the transportation of materials to production plants, as well as the importance of transparency. According to Eft's 2018 analysis (Eft, 2008), material and product flows are subject to certain risks, particularly those related to demand quantity. The volume of demand rises as a company expands its inventory to include more products or variations of its products. Predicting distribution between product variants can be challenging, especially when considering the unpredictability of some products. To cater to specific regions or countries, there is a requirement for localization of certain products. This necessitates the need for accurate demand forecasts. As each region poses unique challenges for tailored sales, individualized sales strategies are necessary. Attempting to market standardized products can be difficult, if not impossible. According to C.S. Tang and Tomlin (Tang, 2009), products can be found in regions beyond their intended distribution areas. Ascertaining the root cause of demand risks may not always be feasible as there may not be a specific event that triggers them.

The market is predominantly driven by customers' preferences, ultimately determining their purchasing behavior. Psychology can provide a rational basis for some actions. However, certain disruptions may be warranted and have valid justifications. When events or circumstances are set into motion, it can have a consequential impact. For instance, a

downtrend in the economy is a clear sign of a decrease in demand. The deduction drawn from the theory is that there will be a reduction. Additionally, the potential for a demand-side threat can be invoked. The business's alignment is not met by the supply chain strategy in question. Proper alignment between strategy and customers' needs is crucial. Any misalignment can result in discrepancies and failure to meet expectations. The firm's offerings and the customers' demands exist in a precarious balance, posing inherent risks to the supply chain.

3.3 Operational Risks

Operational risks are typically contained within the primary organization, but this does not necessarily imply that activation is impossible. Internal forces can trigger various events within the organization. Events of equipment or machine failure, along with manufacturing errors, for instance.

According to Manuj and Mentzer's research in 2008 (Manuj, 2008), an excessive amount of modifications in either procedures or technology can lead to a multitude of variations. In addition to internal factors, there exist external elements that may hinder a company's operations, such as instances of cyberattacks on IT systems, disclosure of confidential data, or actions carried out by humans. Instances such as destruction of property, deliberate damage or obstruction of work, labor stoppages, or unintentional mishaps (Manuj, 2008) (Chopra, 2004). Cyber risks pose a particularly significant threat to a company's operations. These risks encompass a variety of potential hazards. Cyber threats have the potential to affect the entire supply chain, even if they originate from external sources. From the standpoint of a firm, cyber threats present a significant danger to their operations. In reality, in accordance with a risk survey conducted by Allianz, which included over 2700 experts, cyber risk was identified as the most significant global risk in 2020 (Allianz, Allianz Risk Barometer 2020, 2020). In the report of 2013, the risk of limited growth ranked 15th, but only 6% of respondents considered it a concerning matter. The number of cyber threats, such as ransomware, data breaches and cyber attacks, has been on the rise. Threats loom large, particularly in the aftermath of data breaches given the economic significance of their impact (Allianz, Allianz Risk Barometer 2013, 2013). The quantity of personal data is expanding at an astonishing pace and has been compared to the value of oil on several

occasions. According to Allianz's reports from 2013 cyber attacks pose a significant risk to various organizations (Allianz, Allianz Risk Barometer 2013, 2013). Even though it's a relatively dated example, the worldwide proliferation of the "love-bug" computer virus remains a prime illustration of cyber risk. At the turn of the millennium, numerous significant institutions were deeply affected. Some of the most prominent organizations include the Pentagon, NASA, Ford, and the UK Parliament, just to mention a few. Reportedly resulting in billions of dollars worth of estimated destruction (Chopra, 2004). More than 30% of global businesses have identified machine breakdowns as a major concern. As per the results of a survey conducted by Allianz in 2019, which is documented in Allianz's 2020 report (p. 16), 1000 participants expressed their views (Allianz, Allianz Risk Barometer 2020, 2020). The framework indicates that the possibility of machinery malfunction can be attributed to the operational risks, like those affecting the supply side, can also impact the inner workings of a supply chain. The capacity of a company to provide its goods with consistent quality is hugely impacted by a range of factors. Lead time and delivery reliability are among the key factors to consider (Manuj, 2008).

3.4 Environmental Risks

The last set of hazards to consider are the environmental risks that originate outside the system. Any disruption along the supply chain has the potential to affect the entire chain, and in some cases, entire markets.

Disasters such as earthquakes, fires, explosions, hurricanes, and storms are among the external factors that can disrupt the supply chain, whether it is caused by natural calamities, political instability, terrorism, or systemic failures such as power outages. According to (Kleindorfer, 2005), disturbances caused by human actions such as strikes and salary hikes could lead to disruptions. According to (Manuj, 2008), fluctuations in exchange rates pose a threat to currency risks. Global supply chains are particularly significant, given their cross-border operations that span diverse geographic locations. The second greatest apprehension for global enterprises, as per the ranking, was identified to be disturbances in the supply chain. Supply chain disruption can fall under the umbrella of business interruption, such as when fires occur. The report by Allianz 2020 has identified an assortment of risks that can be associated with a unique category (Allianz, Allianz Risk Barometer 2020, 2020). The

categorization of environmental risk as per the guidelines of this project are listed in the following subchapters.

3.4.1 Calamities

Due to their unpredictability, environmental risks pose a significant challenge. This was highlighted in March 2011 with the Tōhoku catastrophic earthquake. The seismic event known as the Great East Japan Earthquake shook the earth with astonishing force. According to Hayes et al. (2017, p. 91), the fourth strongest earthquake on record, with a magnitude of 9.1, occurred roughly 70km away from the coast which was followed by a tsunami that wreaked havoc and did catastrophic damages in its path. Supply chains were hit hard, and the repercussions were severe. In the aftermath of the earthquake, a staggering 80% of production of automobiles in Japan had come to a halt, with Nissan being one of the affected companies experiencing a significant loss in capacity of about 270.000 cars. Toyota, one of the biggest car manufacturers worldwide, had to delay the release of two of their models in the aftermath of the earthquake.

It is challenging to predict an earthquake over an extended period, and even if it were possible, the opportunities to prepare would be limited. The chances of an earthquake occurring are beyond our control and the resulting impacts may be meager. Half of the top ten hazards for global businesses, as outlined in the Allianz Risk Barometer 2020, are classified as environmental perils (Allianz, Allianz Risk Barometer 2020, 2020) Out of over 1100 insurance claims made by corporations from 2011 to 2018, approximately 33% were the result of storms and water damages. The list of the most pressing supply chain hazards of 2019 has been compiled, and the outcome remains strikingly similar. A total of six of the risks initially identified as environmental hazards maintained their spot in the top ten and classified as risks (Kamal, The top 10 supply chain risks of 2019, 2019). The focus of this work does not encompass the full extent of environmental risks, particularly concerning their extremities.

Without a doubt, the most ubiquitous form of risk for the past four years is related to weather patterns, climates, and natural disasters. The World Economic's Global Risks Report of 2020 indicates that for several years, there has been a certain trend (Forum, 2020). The discussion revolves around the forum report, which presents the top five global risks with an emphasis

on their yearly ranking. Extreme weather, ranked firstly by impact and secondly by likelihood, persisted for four consecutive years. Consistently within the top four in terms of impact, it consistently secures the number one spot in probability. Despite not being geared towards worldwide implications, the report remains significant. The looming threats of disasters, weapons of mass destruction, and societal risks such as water crises pose potential dangers for supply chains is evident and justifies the importance of unpredictable occurrences such as severe environmental conditions on supply chains .

3.4.2 Accidents

Allianz, a trusted insurance partner for diverse global enterprises, has thoroughly scrutinized over 1100 corporate insurance policies. Between 2013 and 2018, there were claims that involved property damage and business losses. The components of interruption are valued at a staggering 7.1 billion USD, with a significant percentage, precisely 30%, belonging to this category.

According to Allianz's 2020 report (p. 15), several incidents were attributed to fires. DHL's findings also revealed that fires on containerships were one of the major causes of concern (Allianz, Allianz Risk Barometer 2020, 2020). In 2019, the most significant hazards to the supply chain included dual infernos that erupted aboard Maersk-operated vessels. These two blazes were listed among the top ten supply chain risks of the year. The early months of 2019 saw numerous ship fires, following a similar trend in 2018. These incidents are not uncommon, and cargo ships, in particular, are prone to catching fire. The inadequacy of load securing was identified as the root cause (Kamal, The top 10 supply chain risks of 2019, 2019) thereby highlighting a deficiency. Fires like this can be classified as either operational risks or supply chain disruptions, highlighting the importance of worker diligence. The view of risks may vary depending on the perspective, for example, operational hazards for the logistics company running the vessel. The logistics company is focused on the supply-side for their clients. This indicates that the lines separating the various aspects of logistics services are not always clear-cut. Categories can be fluid at times.

3.4.3 Political Instability – Regulatory Restrictions

Environmental supply chain threats often arise from political turbulence. The past year has seen numerous protests that have had a significant impact. Instances of turmoil, as observed in Hong Kong, Chile, and France, have had a significant impact on international enterprises, leading to substantial property losses. Amidst the uproar against the Chilean government, there were severe repercussions in the form of business interruptions and damage. For instance, numerous supermarkets, Walmart included, were forced to shut down for a prolonged duration. According to Allianz's 2020 report (p. 15), the suspension of business operations resulted in significant financial losses (Allianz, Allianz Risk Barometer 2020, 2020).

This is not the only cause, however. Trade wars, tariffs, and sanctions fall into the political and regulatory risk category as high-risk factors. The ongoing trade dispute between the USA serves as a prime example of a fully-fledged trade war. In early 2018, products imported from China faced an average of tariffs in the United States. In a shocking turn of events, the percentage has skyrocketed from 3.1% to an astonishing 19.3% as reported by Bown in 2020. This serves as a clear example of the negative impact that has befallen (Bown, 2020). The 31st of January 2020 marked the official implementation of the Brexit (EU, 2019), which has had a significant impact. As per Nakamura et al. the effects of this will be felt heavily across worldwide supply chains (Nakamura, 2019).

3.4.4 Diseases- Pandemics and Epidemics

Epidemics and pandemics pose an environmental hazard that is unlikely to arise, but if they do, the consequences can be dire. Frequently, the repercussions can be severe. In light of viral outbreaks, travel constraints may be enforced. The consequences of this could be severe, including limitations on material transportation, and even the possible shutdown of manufacturing plants. The impact would be far-reaching. There is a broad spectrum of literature that explores the impact of epidemics and pandemics on supply chains. Research efforts are primarily centered on influenza outbreaks, as noted by Queiroz et al. (Queiroz, 2020).

To effectively analyze the impact of epidemics and pandemics, it is most useful to examine a specific example. The outbreak of Coronavirus in 2020, widely referred to as COVID-19

pandemic. Epidemics and pandemics continue to serve as prime examples of ongoing disruptions to society. The 2020 COVID-19 pandemic has significantly impacted global supply chains. A recent survey of 300 professionals in shipping and freight revealed the extent of the disruption caused (Resource, 2020). When surveyed, nearly 98% of those asked responded that they believed the coronavirus had impacted "professionals" to some degree. Among those surveyed, the majority (58.8%) reported that their operations were significantly affected and a mere 1.3% indicated that there was no impact whatsoever. Despite ongoing efforts to contain it, the virus persisted. The magnitude of this worldwide upheaval is striking. Supply chains spanning the entire globe have been rattled to their core. It's currently impossible to fully evaluate the extent of the disruption caused, as it has shaken the very foundations. The pandemic still rages on across the globe, with its consequences as yet unresolved. The majority of countries witnessed a detrimental setback in Q1 of 2020, as evidenced by negative GDP growth. As Jones et al. (2020) reported, the impact of the pandemic was felt globally (Jones, 2020). Supply chains were severely disrupted, creating a wide range of challenges. The current state of unpreparedness is exemplified in the scarcity of hand sanitizers. The inability to cater to such large quantities of demand arose as the supply chains were not designed to handle such volumes. While the pandemic caused an unprecedented surge in demand for many products, the toilet paper shortage was a unique case. The tumultuous onset can be traced back to the point where frenzied selling began to take hold, exacerbated by incessant media coverage. After the initial spike levelled off, shortages continued to persist despite increased capacity. The demand for paper mills was met, but the issue lied in the specific type required. Due to obligatory stay-at-home rules, the demand drastically transitioned to private. The sales of toilet paper declined due to a decrease in public demand from households, schools, restaurants, and companies. The shift was significant, as it made production sites that catered specifically to bulk buyers irrelevant.

Supply chain management aims to avoid inflexibility in all aspects, and these issues serve as prime examples of this objective. An effective strategy for supply chain management is one that is adaptable and capable of responding to changes in demand. The shift in market conditions led to an increase in private demand, which unfortunately, the supply chains failed to keep pace with. It is crucial to take into account the industrial demand in order to effectively manage the supply chain strategists. There exist several significant disruptions in the global supply chains that have a more substantial economic impact. The greater

magnitude of the issue poses a heightened threat to human health, while also being one of the toughest economic challenges. Restrictions on travel have already left their mark on the automotive sector. To begin with, the industry has been hit hard by these measures, with the full extent of the impact yet to be seen. In the automotive industry, international sourcing is a significant factor. However, this often results in a shortage of parts supply. Furthermore, in 2020, virtually all significant car manufacturers were compelled to shut down their factories, as reported by Reuters.

In conclusion, the decrease in demand hit hard. Additionally, the pharmaceutical sector underwent changes during the same period. It's important to safeguard against sudden jolts that could severely impact this vital industry - especially during times of global significance. As the world grapples with a health emergency, India holds a crucial role as a leading manufacturer of paracetamol. This essential medicine is widely utilized in the treatment of COVID-19. Generics production in India heavily relies on China as the primary source of its ingredients, despite potential symptoms this may cause with Hubei being among the regions served by the world's leading supplier of active pharmaceutical ingredients.

4. Global Impacts

4.1 Impacts on the global supply chain from COVID-19

In order to curb the spread of COVID-19, a multitude of countries globally adopted measures to control the outbreak by enforcing lockdowns and other social distancing techniques. Over time, limitations brought about changes in worldwide social customs and movements. The outcome of this was a seemingly chaotic upheaval of both social and economic functions.

4.1.1 Alterations in the Markets

As COVID-19 began to impact the world in early 2020, the economy's decline made its first appearance, since regulatory and governmental health related restrictions affected the

consumers' ability to access stores as well as consumers' uncertainty with regards to their occupation and potential loss of income pushed them to minimize their consumption. The industry does not foresee future increases in demand and developments in supply and as a result, importers also began to import less and correspondingly the shipping companies started to reduce their capacity.

Demand started to increase dramatically as people started consuming online since the concept of home office was implemented, so consumers' uncertainty about their income decreased and thus the demand for online purchases increased. As a result importers rapidly increased their imports with the shippers facing a surge in demand that was in contrast to the previous market behavior. This resulted in every carrier vessel being overbooked and prices for a booking to reach unprecedented high levels. The gradual increase of e-commerce had begun even before the COVID-19. However, the online purchases have peaked throughout the pandemic, an event highly visible in the Maritime Supply Chain which was not ready to face the massive increase in transportation demands and, in most cases, lacking the infrastructure to support it. Peaks and valleys in freight rates were visible before the pandemic as well but not at these proportions. The overall increase in shipping rates, even though benefited the overall revenue of shipping organizations, it also presented additional costs that were not applicable before. In order to meet demand, additional investments had to be made to meet the increasing demand, with the possibility of these investment to become a liability for the company in case demand falls, being a future threat.

4.1.2 Capacity Shortage

The biggest challenge during the pandemic appears to be capacity utilization in ports, ships, and cargo handling workers. A great number of ports around the world have been facing congestion due to irregular ship schedules that arise from fluctuating demand, with this having a massive impact on the overall maritime supply chain, where an additional week of port stay could have a ripple effect on the whole of the supply chain. The problem is evident in Chinese ports where authorities enforce lockdowns whenever an epidemic outbreak is happening, leaving ships for days or even weeks waiting to load or discharge their product. Such irregularities further increased the fluctuations in deliveries of cargo, accentuating the disruption in the timely delivery of goods to the end users.

Clearly, terminal capacity at port is a great issue, more importantly when it is related to containers stockpiling at destination ports. With this issue being inflamed due to mist ports locations, being in cities, where the storage areas are finite and underlined by city limits. When limitations like the lockdowns of all operations, hinder the operations of a port, the result is more cargo being stockpiled at the port without any means of exporting it for new cargo to be off loaded. Ports are highly dependent on the reliability of vessel schedules and by hindering loading and discharging operations, congestion is inevitable and more vulnerabilities make it to the surface.

In addition to the above, the restrictions caused by measures against the further spread of COVID-19, have gravely affected labor. While in the pre- COVID-19 era, workers handling containers were carefully scheduled and rotated in fully manned shifts, during the pandemic, the workforce was limited and therefore shortages in manhours per container were limited. This resulted in even more delays in shipments as well as in the loading and discharging of cargo that further accentuated the congestion at ports and the increase of operational costs for the carriers that was ultimately shifted towards the consumers. Apart from the port workforce, the office staff was also facing a different than before work situation. Having to work from home, detached from the reality and day to day work, led to various communication problems that led to even further delays in the delivery of goods.

4.1.3 Long term developments

Having faced the effects of the COVID-19 pandemic for the past three years, experts in the maritime supply chain market have started to make predictions on the long term developments that this on going situation will hold for the future. The effects of the pandemic have forever changed the face of the supply chain sector, with the shipping business not being an exception. Businesses had to adapt to the new status of things that has yet to turn back to its former status. In the aftershock of the pandemic, even smaller events like a storm or a hurricane, tend to be impact more emphatically the industry, which is trying to avoid dramatic losses like the ones that occurred in the early stages of the pandemic, rendering the decision makers more reserved in their decisions.

4.1.4 Lessons learned- Resilience

The majority, if not the whole, of the maritime industry decision makers, were not prepared for a disruption of the magnitude of the COVID-19 pandemic. Quite on the contrary, more investments were made towards reducing risks of cybersecuti or terrorism. In general, and given the volatile nature of the industry, shipping companies are invested in Risk Assessment and Risk management, with both being an integral part of their management system. Crisis management is not a new concept for the maritime business, even though in a smaller scale than a worldwide pandemic.

An initial reaction of the shipping companies towards the disruptions caused by the pandemic restrictions, were the sufficient stocking of spare parts for vessel maintenance and most importantly the adequate and uninhibited provisions supply on board their vessels. The seafarers welfare was the number one priority, and that included the strive for safety, well being and safe disembarkation in case of need. All of which was interlocked with the uneventfull operations of the ships to fulfill their objective, ie delivering their products to ports even with delay. In order to achieve that, shipping companies had to adapt their ways into the new era. Change of IT hardware, from destk tops to laptops were introduced, so that work from home option was more easily accessible, making the workforce more flexible. Stakeholders have learned from the impact of COVID-19 which has led to further increased capacity for every stage of the pandemic, thus making the maritime supply chain more agile and flexible. Even if the industry was not specifically prepared for the impact of COVID-19, it is evident that their resilience has increased during the pandemic due to the disruption

4.2 Impacts due to Suez canal blocking

The impact of Suez Canal Blockade-21 was "more or less immediate".In fact, the impact is not as severe as one might assume. There were adequate measures for laden vessels to avoid accidents and collisions and in this particular case, the options of bypassing the canal and going around it was ain option, even though a more expensive one.

4.2.1 Re routing

With the Suez Canal Blockage of 2021 being the most major incident in its history, the vulnerabilities of this specific passage were highlighted thus forcing maritime decision makers to re evaluate their schedules. The transportation of cargo via the Suez canal has always been the fastest and more cost effective routing choice for shipping companies who now have to reconsider their options. Rerouting however via South Africa is far more time consuming and expensive and given the rarity of such incidents in the area historically, it is highly improbable that any thing like this will happen again. This incident has been incorporated in many shipping business risk assessment plans as a case study and the use of the Canal has been classified as a calculated risk by most experts in the field.

4.2.2 Interaction with the Media

The Suez Canal Blockage was not the first ever disruption to have hindered the smooth operations of the Maritime Transport Sector. However, the media attention that this incident gathered, was unheard of. The information and the coverage of the incident at Suez was unprecedented and it can only be compared to occurrences such as maritime accidents of previous years like maritime catastrophes. The public was overwhelmed with relevant information and perhaps it was the first time that the actual workings of the transportation industry were showcased and felt by the end users., ie the consumers of the goods transported globally via various transportation modes. The media showcased the weaknesses of the MTS using as an example the blockage of the Suez canal and the need of investing in infrastructure was made public and evident.

4.2.3 Lessons learned- Resilience

The majority of the shipping industry stakeholders were better prepared to handle this type of disruption like a canal blockage, than COVID-19. This is due to the fact that the Suez canal had indeed blocked several times in the past, but without the impact the latest blockage had. Thus they were better prepared and had relevant experience to take reparatory actions to minimize impact and return to normal operations the soonest possible. However the timing of the Suez Canal blockage was the factor that increased the importance of this

specific occasion. Ports had already been pressured from the COVID-19 bottlenecks and congestions that had occurred due to protective regulatory measures from port authorities and the further delays in cargo deliveries and disruptions the blockage initiated added to an already strenuous situation.

Initially and in the first few hours that the news broke regarding the Suez Canal blockage, concerned parties, such as shipping companies and various stakeholders involved in the industry, as per their contingency and preparedness action plans, would set up task forces to break down the incident parameters and take counter measures to mitigate their losses. Either that is media coverage, identifying which of their vessels might be affected by the blockage or even communication with seafarers families for avoiding crises. For the vessels that were stuck in the convoy the only solution was to wait for the un blocking, and for the ones that were due to call the Suez Canal was to avoid it and sail towards South Africa, even if the would not be cost efficient, but still losses of income would have to somehow be mitigated. In a few cases, shippers would transport their cargo by trucks but that proved to be expensive and time consuming due to additional costs of unloading cargo from ships and loading it to trucks that would have to be hired, thus adding to the total operational cost. The Maritime Transport Sector, due to the nature of the business was already implementing resilience measures towards disruptions, such as preparedness, responsiveness, recovery and learning and growth capabilities as indicated above.

The impact of COVID-19 and the Suez Canal Blockage-21 made it prominent that organizations would need to invest in the increase of their flexibility in their operations and processes with adaptability being a key factor in the overall scheme of things. Before the pandemic, the percentage of the workforce working from home offices was close to zero and the companies that managed to rapidly turn over this situation were the ones that faced less losses. On the other hand not all occupations can be performed from a home office, like stevedores and cargo handlers at ports, however the use of technology with the implementation of automations in terminal stations could assist in that direction and this falls into the category of infrastructure investment that is required to increase flexibility and adaptability in ports. The high costs involved in such an investment are indeed high, however the cutbacks and losses of income for all involved parties would need to be considered.

Response and recovery from a disruption comes in the form of an organizations capability in agility. Understanding and recognizing the threat in normalcy and the speed in which it

happens affects the level of agility an organization holds. Reaction speed to disruptions is one of the most important factors in building resilience in a company since the earlier a situation is confronted, the faster the actions that need to be taken will occur. Reliability and quick adaptation are key aspects in keeping goods flowing within the supply chain and findings showed that stakeholders learned as the pandemic evolved, with their agility and flexibility increasing.

MTS stakeholders consider visibility in the maritime sector of high importance when faced with disruptions. In the example of the Suez Canal Blockage-21 not all shipping companies were aware of the exact containers that were affected by the blockage. That is related to the lack of information flow and knowledge within organizations resulting in lack of information towards ports of discharge where no information was given as to how many containers they would or would not receive. Transparency together with reliability are of paramount importance in the transportation system and once again this disruption of information was showcased by an unexpected event like the Suez Canal Blockage-21.

One of the main problems exposed by the blockage was the lack of integration and collaboration between interested parties in the maritime supply chain. Sharing information is important to reduce risk and respond to disruptions. Different involved parties have their own information systems and flows that most currently do not communicate directly with other information flows thus hindering the exchange of information. This is something that will need to be considered by maritime transport sector specialists in order for optimum solutions can be found to avoid miscommunication and misinformation.

5 Conclusion

In our modern era, global supply chains are continuously expanding alongside the shifting demands of consumers. Regardless of the pace of change, one factor remains unchanged: Consumer demand for swift delivery, superior quality, and impeccable product standards. Flawless global supply chains are imperative for maximal customizability. To ensure smooth operations, it's imperative for companies to tackle potential risks faced by their international supply chains. To stay ahead in the game, maintaining competitiveness is crucial. It demands a well-planned strategy to tackle potential risks in the supply chain.

The subject at hand revolves around nature and its potential impact on global supply chains. Risk assessment is proposed through four categories: supply-side risks (towards suppliers upstream), demand-side risks (towards customers downstream). Risks that pertain to the inner workings of a company, such as operational hazards, can be distinguished from those originating from the surrounding environment, such as external threats to the supply chain. Extra classifications could be required, based on the individual circumstances of a corporation, such as the impact across their entire supply chain. These fundamental categories are deemed essential and must be included when introducing the topic.

Merely possessing a competent supply chain strategy is inadequate, given the numerous hazards that must be managed. Businesses must not assume seamless operations at all times. It is crucial to anticipate potential disruptions and plan accordingly. Attempts to anticipate, alleviate, and implement suitable countermeasures in response to them. Effective management of disruptions is crucial. Therefore, this thesis focuses on disruption management. The utilization of a universal framework is suggested for implementing an effective supply chain risk management strategy. In the event of any disturbance, substitutes should be on hand. Collaboration is integral to the company's modus operandi, as it maintains close ties with suppliers upstream. Collaboration with partners downstream facilitates sharing of information and resources, mutual gains, and risk distribution. Maintaining a surplus of suppliers and plants across multiple countries is of particular significance for the sake of redundancy. It is crucial to ready the global supply chains in anticipation of any possible regional challenges. Investments in infrastructure are a necessity in maritime transport systems to strengthen the global supply chains by enhancing intermodal infrastructure, fleet renewal and improving port performance and trade facilitation. Further operational research, involving maritime companies and port authorities, with relevant data collection and analysis would further showcase the risk management involved in disruptive events and the preparedness that is required to overcome them.

References

- Alamoush, A. S. (2021). The immediate impact of COVID-19 and the way forward. *Maritime Technology and Research*, 1-26.
- Ali, A. M. (2017). Analysing supply chain resilience: integrating the constructs in a concept mapping framework via a systematic literature review. *Supply Chain Management*, 16-39.
- Allianz. (2013). *Allianz Risk Barometer 2013*. Allianz.
- Allianz. (2020). *Allianz Risk Barometer 2020*. Allianz.
- Asadabadi, A. &-H. (2020). Maritime port network resiliency and reliability through co-opetition. . *Transportation research. Part E, Logistics and transportation review*.
- Barroso, A. P. (2011). Supply Chain Resilience Using the Mapping Approach. In L. Pengzhong. *Supply Chain Management*, 161-184.
- Berle, O. A. (2011). Formal Vulnerability Assessment of a maritime transportation system. *Reliability engineering & system safety*, 696-705.
- Bichou, K. &. (2004). A logistics and supply chain management approach to port performance measurement. *Maritime Policy & Management*, 47-67.
- Bown, C. P. (2020). US-China Trade War Tariffs: An Up-to-Date Chart. *Peterson Institute for International Economics*.
- Brooks, M. R. (2006). Devolution, port governance and port performance. *Elsevier*.
- Brusset, X. &. (2017). Supply chain capabilities, risks, and resilience. *International journal of production economics*,, 59-68.
- Carbone, V. &. (2003). The changing role of ports in supply-chain management: an empirical analysis. *Maritime Policy & Management*, 305-320.
- Chan, F. T. (2007). Global supplier development considering risk factors using fuzzy extended AHP-based approach. *Omega*,, 417-431.
- Chari, A. N.-D. (2022). Dynamic capabilities for circular manufacturing supply chains—Exploring the role of Industry 4.0 and resilience. *Business Strategy and the Environment*,.
- Chopra, S. &. (2004). Managing Risk to Avoid Supply-Chain Breakdown. *MIT Sloan Management Review*.
- Christopher, M. M. (2011). Approaches to managing global sourcing risk. *Supply Chain Management: An International Journal*, 67-81.
- Christopher, M. P. (2004). A taxonomy for selecting global supply chain strategies. *The International Journal of Logistics Management*, 277-287.
- Closs, D. N. (2010). The differential impact of product complexity, inventory level, and configuration capacity on unit and fill rate performance. *Journal of Operations Management*, 47-57.
- Cullinane, K. &. (2021). Global trends in maritime and port economics: the COVID-19 pandemic and beyond. *Maritime Economics & Logistics*, 369-380.
- Diabat, A. G. (2012). Supply chain risk management and its mitigation in a food industry. *International Journal of Production Research*, 3039-3050.

- Dürr, G. M. (2021). Suez Canal Blockage: Ship Freed, Heavy Traffic, International Impact. *History and Government Faculty Contributions to the Popular Press*.
- Eckstein, D. G. (2015). The performance impact of supply chain agility and supply chain adaptability: the moderating effect of product complexity. *International Journal of Product Research*, 3028-3046.
- Eft. (2008). *What is the biggest challenge you are facing in your supply chain?* Retrieved from <https://www.statista.com/statistics/829634/biggest-challenger-supply-chain>
- Er Kara, M. &. (2017). Supply chain risks: Literature review and a new categorization. *Beykent University Journal of Science and Engineering*, 31-60.
- Eyob, E. &. (2012). Customer-Oriented Global Supply Chains: Concepts of Effective Management. *IGI Global*.
- Forum, W. E. (2020). *The Global Risks Report 2020*. The World Economic Forum.
- Glock, C. H. (2013). Reducing lead time risk through multiple sourcing: the case of stochastic demand and variable lead time. *International Journal of Production Research*, 43-56.
- Handfield, R. B. (2008). *Supply Chain Risk Management: Minimizing Disruptions in Global Sourcing*. Auerbach Publications, Taylor & Francis Group.
- Hassan, S. M. (2017). Mediating role of operational capabilities between intellectual capital and organizational performance: a proposed theoretical framework. *Academy of strategic management journal*, 1-12.
- Heaver, T. D. (2020). The evolving roles of shipping lines in international logistics. *International journal of maritime economics*, 210-230.
- Ho, W. Z. (2015). Supply chain risk management: a literature review. *International journal of production research*, 5031-5069.
- Hohenstein, N. F. (2015). Research on the phenomenon of supply chain resilience: A systematic review and paths for further investigation. *International journal of physical distribution & logistics management*, 90-117.
- Hohenstein, N.-O. F. (2015). Research on phenomenon of supply chain resilience: A systematic review and paths for further investigation. *International journal of physical distribution & logistics management*, 90-117.
- Hollnagel, E. (. (2011). The Resilience Analysis Grid. *CRC Press*, 275-296.
- Hossain, N. U. (2020). Modeling and assessing interdependencies between critical infrastructures using Bayesian network: A case study of inland waterway port and surrounding supply chain network. *Reliability engineering & system safety*.
- Inman, R. &. (2014). Product complexity and supply chain design. *International Journal of Production Research*, 1956-1969.
- Ivanov D, D. A. (2019). The Impact of digital technology and Industry 4.0 on the ripple effect and supply chain analytics. *International Journal of production research*, 829-846.
- Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/ SARS CoV-2) case. *Transportation research Part E, Logistics and Transportation review* .
- Jansson, J. O. (1982). The optimal ship size. *Journal of transport economics and policy*, 217-238.

- Jian, M. F. (2015). The impact of lead time compression on demand forecasting risk and production cost: A newsvendor model. *Transportation Research Part E: Logistics and Transportation Review*, 61-72.
- Jiang, B. R. (2022). From Just-in-Time, to Just-in-Case, to Justin-Worst-Case: Simple Models of a Global Supply Chain under Uncertain Aggregate Shocks. *IMF Economic Review*, 141-184.
- Johnson, G. W. (2017). *Exploring Strategy: Text and Cases (11th ed.)*. Pearson.
- Johnson, M. E. (2001). Learning from Toys: Lessons in Managing Supply Chain Risk from the Toy Industry. *California Management Review*, 106-124.
- Jones, L. P. (2020). Coronavirus: A visual guide to the economic impact. *BBC News*.
- Jüttner, U. &. (2011). Supply chain resilience in the global financial crisis: an empirical study. *Supply chain management*, 246-259.
- Jüttner, U. (2005). Supply chain risk management. *The International Journal of Logistics Management*, 120-141.
- Juttner, U. P. (2003). Supply chain risk management: outlining an agenda for future research. *International journal of logistics*, 197-210.
- Kähkönen, A.-K. E. (2021). COVID-19 as a trigger for dynamic capability development and supply chain resilience improvement. *International journal of production research*, 1-20.
- Kamal, S. &. (2019). The top 10 supply chain risks of 2019. *Supply Chain Quarterly*.
- Kamal, S. &. (2019). The top 10 supply chain risks of 2019. *Supply Chain Quarterly*.
- Khaslavskaya, A. &. (2019). Outcome-Driven Supply Chain Perspective on Dry Ports. *Sustainability*.
- Kleindorfer, P. R. (2005). Managing Disruption Risks in Supply Chains. *Production and Operations Management*, 53-68.
- Kumar, B. &. (2021). Managing the supply chain during disruptions: Developing a framework for decision-making. *Industrial marketing management*, 159-172.
- Lam, J. S. (2011). Patterns of maritime supply chains: slot capacity analysis. *Journal of Transport Geography*, 366-374.
- Lam, J. S. (2012). *Risk Management in Maritime Logistics and Supply Chains*. Emerald Group Publishing Limited.
- Lam, J. S. (2015). Designing a sustainable maritime supply chain: A hybrid QFD-ANP approach. *Transportation Research Part E: Logistics and Transportation Review*, 78, 70-81.
- LeBlanc, J. K. (2021). Suez Canal Blockage: Ripple Effect on Miami Valley Supply Chain. *Business Administration Faculty Contributions to the Popular Press*.
- Lee, J. M.-y.-c. (2021). Suez Canal blockage: an analysis of legal impact, risks and liabilities to the global supply chain. *MATEC Web of Conferences*.
- Li, G. Y. (2017).). Bullwhip and anti-bullwhip effects in a supply chain. *International Journal of Production Research*, 5423-5434.
- Liu, J. (2011). Global ports and logistics facilitation: Contemporary issues and challenges. *Supply Chain Management and Transport Logistics*, 424-441.
- Lockamy, A. &. (2010). Analysing risks in supply networks to facilitate outsourcing decisions. *International Journal of Production Research*, 593-611.
- Mack, O. K. (2019). *Managing in a VUCA World*. Springer International Publishing.
- Manuj, I. &. (2008). Global supply chain risk management. *Journal of business logistics*.

- Mohammed, A. J. (2021). COVID-19 pandemic disruption: a matter of building companies' internal and external resilience. . *International journal of production research*,, 1-22.
- Nakamura, K. Y. (2019). The impact of Brexit on designing a material based global supply chain network for Asian manufacturers. *Management of Environmental Quality: An International Journal*, 980-1000.
- Notteboom, T. P.-P. (2021). Disruptions and resilience in global container shipping and ports: the COVID-19 pandemic versus the 2008–2009 financial crisis. *Maritime Economics & Logistics*, 179-210.
- OECD. (n.d.). www.oecd.org. Retrieved from www.oecd.org/ocean/topics/ocean-shipping/: www.oecd.org/ocean/topics/ocean-shipping/
- Ohmori, S. H. (2019). Global logistics network design problem with rules of origin. *Journal of Industrial Engineering and MAnagement*, 447.
- Palagyi, S. (2004). Making The Supply Chain A Strategic Asset. *World Trade*, 38-40.
- Panayides, P. M. (2012). Supply chain integration of shipping companies. *Maritime Logistics: A complete guide to effective shipping and port management*, 101.
- Pettit, T. J. (2010). Ensuring supply chain resilience: development of a conceptual framework. *Journal of business logistics*, 1-21.
- Pettit, T. J. (2013). Ensuring Supply Chain Resilience: Development and Implementation of an Assessment Tool. *Journal of business logistics*, 46-76.
- Ponomarov, S. &. (2009). Understanding the concept of supply chain resilience. *The international journal of logistics management*, 124-143.
- Prokop, D. (2017). Global Supply Chain Security and Management Appraising Programs, Preventing Crimes. *Elsevier Inc*.
- Queiroz, M. M. (2020). Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review. *Annals of Operations Research*.
- Ravindran, A. R. (2010). Risk adjusted multicriteria supplier selection models with applications. *International Journal of Production Research*, 405-424.
- Resource, S. a. (2020). *How has the coronavirus impacted your operations?* Retrieved from www.statista.com: <https://www.statista.com/statistics/1129401/impact-covid-supply-chains>
- Rosenberg, S. (2018). The Global Supply Chain and Risk Management. *Business Expert Press*.
- Russell, D. R. (2020). Managing supply chain uncertainty by building flexibility in container port capacity: a logistics triad perspective and the COVID-19 case. *Maritime economics & logistics*.
- Schmitt, A. J. (2012). A quantitative analysis of disruption risk in a multi-echelon supply chain. *International Journal of Production Economics*,, 22-32.
- Scholten, K. &. (2015). The role of collaboration in supply chain resilience. . *Supply chain management*, 471-484.
- Sheffi, Y. &. (2005). A Supply Chain View of the Resilient Enterprise. *MIT Sloan management review*, 41.
- Shishodia, A. S. (2021). Supply Chain Resilience: A review, conceptual framework and future research. *The International Journal of logistics Management*.

- Sindi, S. &. (2017). *Strategic Supply Chain Management*. Springer International Publishing.
- Singh, C. S. (2019). Performance indicators for supply chain resilience: review and conceptual framework. *Journal of industrial engineering international*, 105-117.
- Skiba, S. &. (2022). The Changing Role of a Freight Forwarder in Modern Supply Chains. *European Research Studies Journal*, 25(1), 341-351.
- Talluri, S. N. (2006). Vendor performance with supply risk: A chance constrained DEA approach. *International Journal of Production Economics*, 212-222.
- Tang, C. S. (2009). *How Much Flexibility Does It Take to Mitigate Supply Chain Risks?* Springer Science+Business Media.
- Teece, D. J. (2007). Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. . *Strategic management journal*, 1319-1350.
- Tukamuhabwa, B. R. (2015). Supply chain resilience: definition, review and theoretical foundations for further study. *International journal of production research*, 5592-5623.
- Van Der Horst, M. R. (2008). Coordination in hinterland transport chains: a major challenge for the seaport community. *Maritime Economics & Logistics*, 108-129.
- Van Wassenhove, L. (2006). Humanitarian aid logistics: supply chain management in high gear. *The Journal of the Operational Research Society*, 475-489.
- Wan, C. Y. (2018). Resilience in transportation systems: a systematic review and future directions. *Transport reviews*, 38(4), 479-498.
- WHO. (n.d.). *Coronavirus disease (COVID-19)*. Retrieved from www.who.int: www.who.int/health-topics/coronavirus#tab=tab_1
- Yazdani, B. (1999). Four Models of Design Definition: Sequential, Design Centered, Concurrent and Dynamic. *Journal of Engineering Design*, 25-37.
- Zavala-Alcívar, A. V.-J.-S.-J. (2020). A Conceptual Framework to Manage Resilience and Increase Sustainability in the Supply Chain. *Sustainability*.

Author’s Statement:

I hereby expressly declare that, according to the article 8 of Law 1559/1986, this dissertation is solely the product of my personal work, does not infringe any intellectual property, personality and personal data rights of third parties, does not contain works/contributions from third parties for which the permission of the authors/beneficiaries is required, is not the product of partial or total plagiarism, and that the sources used are limited to the literature references alone and meet the rules of scientific citations.