MANAGING DISRUPTION RISKS IN B2B ELECTRICAL EQUIPMENT SUPPLY CHAINS

A Case Study

Lappeenranta–Lahti University of Technology LUT

Masters Programme in Supply Management, Master's thesis

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ABSTRACT

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Managing disruption risks in B2B electrical equipment supply chains: A case study

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This master's thesis explores the impact of disruption risks in the electrical goods sector's B2B supply chains, with a specific focus on availability concerns. It analyzes practical risk assessment and mitigation models applied in the sector over the past five years, emphasizing the B2B electrical wholesale sector and its suppliers. Insights are drawn from interviews with three companies operating in this field.

The study identifies four significant disruptions in the last five years – the COVID-19 pandemic, the Russia-Ukraine war, the Suez Canal blockade, and floods in Central Europe. These disruptions have led to supply chain blockages, logistical challenges, shortages of critical components, disruptions in the supply of materials like steel, aluminium, and copper, price hikes, and disturbances in international supply chains.

The research highlights that effective mitigation models are context-specific, with no universally applicable solutions. However, it identifies successful strategies, including fostering collaboration for a flexible supply chain, maintaining vigilance and agile responses, conducting comprehensive supply chain analyses, ensuring supplier vigilance and sustainability assessments, emphasizing contract accuracy and transparent communication, diversifying with both primary and secondary suppliers, optimizing inventory management, strategically diversifying product offerings, reducing supplier risks through geographical proximity, employing information systems for real-time monitoring, and implementing continuous monitoring for proactive response.

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Tässä Pro Gradu -tutkielmassa tutkitaan häiriöriskien vaikutusta sähkötarvikealan B2B-toimitusketjuihin ja keskitytään erityisesti saatavuusongelmiin. Siinä analysoidaan tehokkaita riskien arviointi- ja lieventämismalleja, joita on sovellettu alalla viimeisten viiden vuoden aikana, painottaen sähköalan B2B-tukkukauppaa ja sen toimittajia. Tiedot perustuvat kolmen alalla toimivan yrityksen haastatteluihin.

Tutkimuksessa yksilöidään neljä merkittävää häiriötä viimeisten viiden vuoden aikana: COVID-19-pandemia, Venäjän ja Ukrainan sota, Suezin kanavan tukkeutuminen ja Keski-Euroopan tulvat. Nämä häiriöt ovat johtaneet toimitusketjujen tukkeutumiseen, logistisiin haasteisiin, kriittisten komponenttien puutteeseen, häiriöihin materiaalien, kuten teräksen, alumiinin ja kuparin, toimituksissa, hintojen nousuun ja häiriöihin kansainvälisissä toimitusketjuissa.

Tutkimuksessa korostetaan, että tehokkaat lieventämismallit ovat kontekstisidonnaisia, eikä niihin ole yleispäteviä ratkaisuja. Tutkimuksessa yksilöidään kuitenkin menestyksekkäitä strategioita, kuten yhteistyön edistäminen joustavan toimitusketjun luomiseksi, valppaan ja ketterän reagoinnin ylläpitäminen, kattavien toimitusketjuanalyysien tekeminen, toimittajien valppauden ja kestävyyden arvioinnin varmistaminen, sopimusten täsmällisyyden ja läpinäkyvän viestinnän korostaminen, monipuolistaminen sekä ensisijaisten ja toissijaisten toimittajien kanssa, varastojen hallinnan optimointi, tuotetarjonnan strateginen monipuolistaminen, toimittajariskien pienentäminen toimittajien maantieteellisellä läheisyydellä, tietojärjestelmien käyttö reaaliaikaista seurantaa varten ja jatkuvan seurannan toteuttaminen ennakoivaa reagointia varten.

ABBREVIATIONS

B2C Business to Consumer market

B2B Business to Business market

SCM Supply chain management

SCRM Supply chain risk management

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1 Introduction

The importance of risk management in modern society and business has grown, especially in recent years. As a result of the COVID-19 pandemic and the war between Russia and Ukraine, supply chains, especially availability, have experienced many new problems and disruptions. The consequences of the pandemic were already felt in 2020 when production facilities were temporarily closed, and supply chains started to show signs of disruption. Availability risks increased, and many companies experienced availability problems in key product categories. Knox (2023) mentions that this risk increased further due to the war in Ukraine over the past year. Component prices have risen, availability has become more complex, and this has caused several disruptions for different companies across the supply chain. As a result, anticipating disruptions has become particularly important for companies. As Narasimhan and Talluri (2009) mention in their text, supply chain risk management has become an essential topic in supply chain management. The topic has emerged as a result of several trends in the field. The rise of strategic outsourcing, the globalization of markets, the increasing reliance of firms and suppliers on specialized capabilities and innovation, and the reliance of supplier networks on competitive advantage have all contributed to the growing importance of risk management (Tang & Musa, 2011). Advances in information technology have enabled the management and coordination of large supply chains. Risk management has thus become a more critical part of procurement than previously thought.

This thesis aims to examine risk management in the electrical equipment supply chain. A B2B electrical wholesale company operating in a global market was chosen as the subject of the study. In addition, two suppliers of this company who are also active in this sector were interviewed. Their risk management practices about these availability risks, how they react to unexpected problems in their supply chain and how they deal with them in the short and long term will be investigated. The study also examines the probabilities of risks through risk mapping. It explores the best risk mitigation strategies when a problem occurs and how they are most effectively addressed. Therefore, the study will provide a broad picture of supply chain risk management, particularly availability risk during disruptions, and their problem-solving and risk management.

1.1 Backround and Context

As mentioned above, supply chain risk management has become essential to day-to-day business in recent years. This is why it is essential to identify these disturbances. Over the last five years, there have been several disruptions that have had an impact on supply chains in the form of availability disruptions. These include the COVID-19 pandemic, the Russo-Ukrainian war, the Suez Canal obstruction and the Flood Catastrophe in Europe.

The first notable disruption was the COVID-19 pandemic, which broke out in December 2019 in Wuhan, China, due to pneumonia. According to Ciotti, Ciccozzi, Terrinoni, Jiang, Wang and Bernardini (2020), it was a virus (SARS-CoV-2) that caused thousands of deaths and, as a result, COVID-19 was very quickly declared a global pandemic by the World Health Organisation. The declaration took place on 12 March 2020. This pandemic had a significant impact on the loss of life and on the general economy on a global scale, which also increased poverty. However, what is essential for this thesis is the economic damage caused by the pandemic and, therefore, the impact on supply chains, which was huge, as a large part of the supply chains originated in Asia and especially China, where the pandemic started. (Ciotti et al., 2020) Another significant disruption has been the Russo-Ukrainian war, which started in 2014. It is a war between Russia and Ukraine. In February 2022, Russia launched a full-scale invasion of Ukraine and began to occupy more land, making the situation much worse. Other countries responded with political consequences and sanctions, leading to a freeze on exports and imports. This also had a significant impact on the economy and, therefore, on supply chains, as Russia was an importing and exporting country for very many countries. (Lo, Marcelin, Bassène, Sène, 2022)

One more disruption worth mentioning was the Suez Canal obstruction. In March 2021, a container ship blocked the Suez Canal in Egypt. As a result of high winds, the ship wedged through the channel and could not be repaired for six days. This ultimately had consequences for trade, as the Suez Canal was one of the busiest trade routes in the world. The effects were particularly felt in trade between Europe, Asia and the Middle East. About 15 to 17 USD billion has been held up during this time. Supply chains were thus the most affected, and

shortages in availability were immediately noticed. (Lee and Wong, 2021) In addition, natural phenomena, such as the catastrophic floods in central Europe in July 2021, have caused disruption. Mohr et al. (2023) mention that catastrophic floods occurred in Germany, Luxembourg and Belgium, causing deaths and extensive damage. These floods and mudslides also had severe economic and infrastructural consequences, as the floods destroyed everything in the areas, including factories. The disruption, therefore, had severe consequences for supply chains, causing disruptions to supply chains and shortages of availability. (Mohr et al., 2023) The COVID-19 pandemic, the Suez Canal obstruction, various natural catastrophes, and the war in Ukraine have all increased the research on disruption risks. The more research that is done, the better the future response to disruptions will be.

Regarding risk management methods, much research has been done in the last couple of years precisely because of the COVID-19 pandemic. Ivanov (2020), El-Baz & Ruel (2021), and NASDAQ OMX (2021) have studied risk management and its importance during a pandemic. However, the electricity equipment sector needs to be comprehensively studied regarding the risk management, making this work significant. It is, therefore, essential to examine how supply disruptions and risks have affected the sector, particularly procurement, and how companies have responded to risk mitigation in recent years. It is also essential to determine whether and how much risk management behaviour has changed due to the crises and how much has been learnt in practice by companies concerning availability problems in the event of disruptions.

1.2 Research Problem and Questions

The main idea of the study is to investigate supply chain disruptions in the electricity supply chain and the associated availability risk. It is also essential to find ways to prevent these situations, which can be achieved through risk identification, combined risk mapping and unlocking mitigation strategies for serious availability risks identified through risk mapping.

The data for the study is obtained through interviews with three companies in the electrical goods sector. In-depth theoretical information will also be obtained from articles on the subject. The interview information will also be used to identify disruption and availability risks, which risk management method works best in these extreme situations, and how such disruptions can be prevented or slowed down. This information is mainly based on the data from the four interviews and, therefore, cannot be fully generalised to all companies in the electrical supply chain. However, these strategies have been implemented in the supply chains concerned.

The study's main objective is to investigate supply chains and disruptions in the supply chain of electrical products and their suppliers, focusing on b2b trade, and to identify possible short- and long-term risk management solutions. It will also investigate which risk management method works best in this context. The study will focus mainly on supply chains through two different suppliers. The study will also identify which aspect of the supply chain has been most affected by disruptions such as natural disasters, wars and pandemics. The study, therefore, focuses mainly on the risk management methods used in supply chains and the impact of different situations on the sector.

This led to two research questions listed below. The upper one is the main research question, and the lower one is a sub-question to elaborate on the main research question:

How to manage supply chain disruptions in the B2B electrical equipment sector supply chains?

What kind of risk management mitigation tools can address disruption and availability risks in B2B electrical equipment supply chains?

1.3 Research Objectives

The study aims to help supply chain risk management issues for companies in different sectors, particularly for companies in the electrical goods sector that buy components from international supply chains and may experience disruptions in their availability. The aim is to help companies identify their weaknesses and risks and find the right short- and long-term strategies to prevent and anticipate disruption and availability risks. This is particularly important today, as the recent past has shown after pandemics and wars. The thesis also provides a good overview of the current state of the electrical equipment supply chain and the risk management methods presented in the current academic literature. In addition, it provides a holistic view of risk management in risk identification, risk assessment and mitigation. The work thus serves as a very comprehensive overview of supply chain management and, in particular, supply chain risk management in the field of electrical supply chains, which may be helpful for companies operating in this field and may provide the academic literature with new insights into the state of the art of electrical supply chains, which has so far been largely unexplored. This work is, therefore, of great importance for the academic literature on supply chain management and risk management and for

companies operating in the sector today, as much has happened in recent years in terms of disruptions, and each disruption behaves very differently and has different consequences.

1.4 Significance of the Study

The benefits of work can be summarised in two main categories: theoretical or academic benefits and practical benefits. At the theoretical level, the study provides a broad overview of risk management in electrical equipment supply chains, especially now that risk management has become increasingly crucial in supply chain management. Therefore, at the academic level, it is vital to investigate the impact of disruptions on the functioning of electrical equipment companies, particularly supply chains, and to explore which risk management mitigation models can contribute to addressing this problem. Moreover, there needs to be more research and more academic literature on supply chain risk management and availability risk in electrical equipment supply chains. Risk mapping is, therefore, also crucial for companies in this sector. In addition, the research can help identify and reflect on short- and long-term solutions at a deeper level, thus serving as a potential example for future research on this topic. The work is, therefore, significant for its novelty, given the disruptions and manifestations of availability problems caused by the war in Ukraine, the COVID-19 pandemic, and other disruptive risks over the last five years. It can help academic research respond in more detail to a topic already being studied and provide more in-depth insight into an area that has not yet been explored. Therefore, The subject is new; the importance of risk management needs to be emphasised, and more research needs to be done on the sectoral level. The work is academically stimulating and essential.

In practical terms, this work can help companies in the electrical goods sector to improve their risk management models and help them prepare for future availability and disruption risks as the importance of risk management in companies continues to grow, as the COVID-19 pandemic and the war in Ukraine have shown. In addition, different companies will see in some detail how their supply chains have performed in these situations. Risk management is still under-researched, and this work can help companies to identify new supply problems

and to anticipate and prevent them in time. The work also links specific disruptions, their assessment models and availability problems to the specific disruption and structures a solution model so companies can see comprehensively how different risks have been addressed over the last few years, and the theory has provided more information on the subject which strengthens companies' self-discovery research. It can benefit companies in the sector as it can serve as a model for the future. Long-term foresight is significant, as solving problems as they arise can lead to more significant losses for the company. The work, therefore, has considerable academic and practical value and can benefit businesses, universities and research institutes alike. Research, therefore, has a wide range of theoretical and practical benefits.

1.5 Structure of the Thesis

The Master's thesis comprises six parts: an introduction, a multi-part theoretical section, a section on research methodology and data collection, an empirical section, a discussion and a conclusion. The first part of the thesis is the introduction, which discusses the importance of the topic, its relevance and the scope of the thesis. It also opens up what the thesis is about. The second part is the theoretical part, which provides the reader with more in-depth information. The theoretical part looks at supply chain management, its details and components. This is followed by an introduction to risk management in procurement and supply chain management and the importance of risk management today. There are also sections on disruption and availability risks, which are relevant to the study. After these disruptions, risk management, risk identification, risk assessment and mitigation will be discussed to explore the topic in more detail.

The theoretical part is followed by a discussion of the research methodology and the data collection method used in the empirical part. The data collection method, a semi-structured interview, is discussed first. The sample size of the data and the companies used in the study are then presented. The second important part of the thesis is the empirical part, which is based on the data obtained from the interviews and secondary data from articles and other

publications. However, the idea behind the secondary data is only to corroborate the information obtained from the interviews; interviews are the primary source of information. The empirical part consists of the main title Risk Management in Electrical Equipment Supply Chains and its three sub-topics: B2B distribution of electrical products, the current state of electrical equipment supply chains, problems encountered in the supply chains of target companies, risk mapping, solutions of target companies to supply chain disruptions in recent years and effective risk mitigation measures to prevent disruption and availability risks.

At the end of the thesis are two more sections: Discussion and Conclusions. The idea of the Discussion is to combine the information from the empirical part with the existing theory and find out whether they align with each other. The Discussion also mirrors the different categories of risk management - risk identification, assessment and mitigation - and compares the data obtained with these important cornerstones of risk management. This is followed by a conclusion of the work, with concluding comments on its success and relevance. Further research topics for the future are also suggested. The structure of the thesis is shown in Figure 1 below.

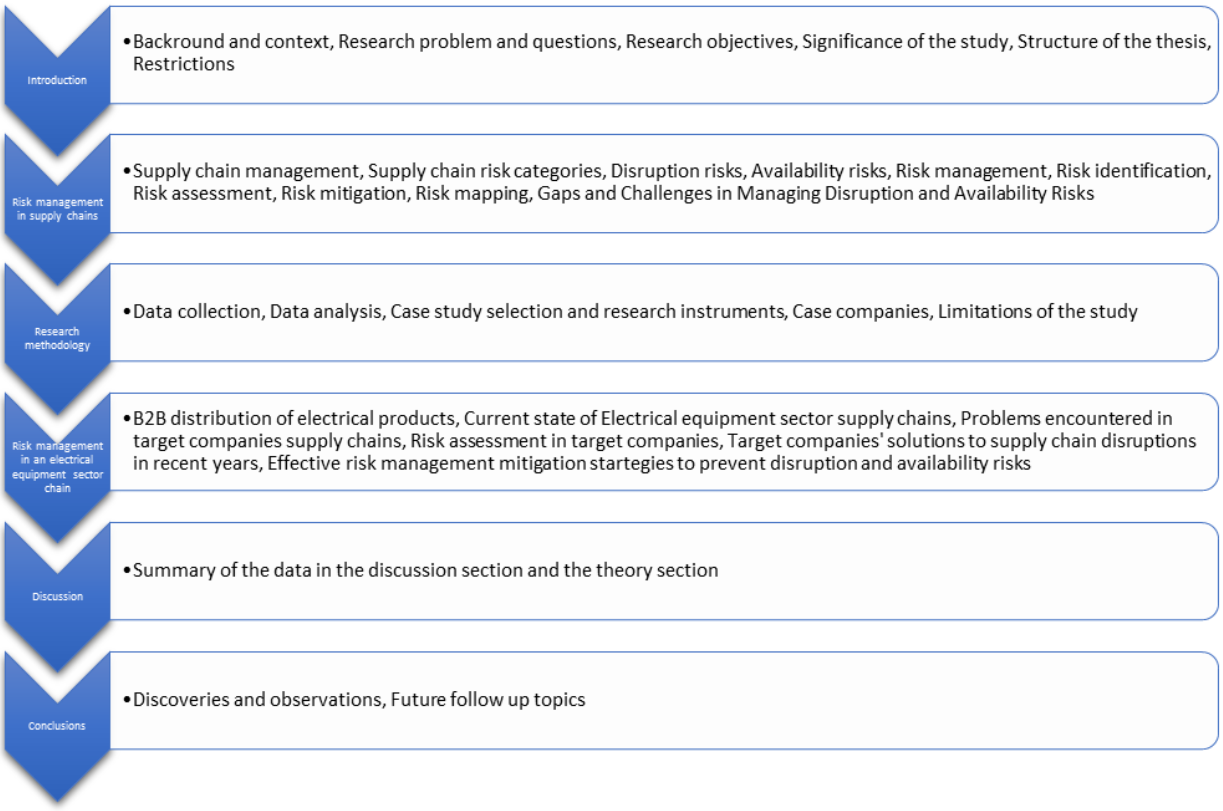

Figure 1: Structure of the Thesis

1.6 Restrictions

Therefore, supply chain management and related risk management are extensive areas of research, making the constraints relevant. The work is generally limited to two risks: disruption risk and associated availability risk. Disruption is only seen as a trigger for availability and is therefore only studied as a trigger for problems. Availability risk and its different categories are, therefore, the focus of this work since different disruptions trigger different availability problems, as seen in the work. Mitigation models have been developed around these risks and will be explored in the work. The work is, therefore, limited to supply chain risk management, identifying different disruption and availability risks, risk mapping for these risks and analysing and exploring possible mitigation strategies. In addition, the empirical part of the work focuses only on the supply chains in the electrical supply industry, which are nevertheless studied from raw material sourcing to resale, as the suppliers of the b2b electrical supply company in question source raw materials for the manufacture of electrical supplies. The work also focuses on only a couple of supply chains, as only two

suppliers of the leading research company, who also supply very different products to the retailer, were interviewed. The work cannot, therefore, be generalised to all companies in the electrical goods sector, as the sample size was small. To summarise, the work specialises in risk management in electrical supply chains and focuses on availability problems caused by disruptions and their risk identification, assessment and mitigation.

2 Risk Management in Supply Chains

This section serves to provide the reader with an introductory understanding of the subject matter, facilitating a clearer comprehension of the information gleaned from the interviews. Commencing with a concise exploration of supply chain management as a broad concept, the narrative then transitions to a brief overview of risk management and its underlying processes. Subsequently, the focus shifts to the specific disruption and availability risks that form the basis of this work, delving into a more detailed examination of the various categories within these risks.

The discussion further extends to a comprehensive exploration of risk management, encompassing the key aspects of identification, assessment, and mitigation. The discourse then delves into the terminology associated with risk mapping, culminating in an exploration of the risk assessment matrix. The concluding segment of the theoretical framework centers on the broader context of the electrical equipment sector, providing insights into the current state of its supply chains and the pre-existing strategies for risk mitigation within the sector.

2.1 Supply Chain Management

Supply chain management (SCM) can be summarised as the integration between departments and companies and the coordination and utilisation of materials, information and cash flows. It is this coordination that is important to ensure that resources are used in the most rational way throughout the value chain. According to Ivanov (2018), the value chain can be classified as all intermediate stages from raw material suppliers, and suppliers

of suppliers, to final customers. SCM can therefore be seen as one of the cornerstones of the modern enterprise, helping to balance supply and demand across the value chain. (Ivanov et al. 2017) Furthermore, Chopra and Meindl (2015) mention in their article that supply chain management can be seen as an integrating factor of the production and logistics process. Therefore, supply chain management problems also interact strongly with production, logistics and other components and are very strongly interlinked. In concrete terms, the impact of supply chain management on firms is, as high as 30%, with supply chain decisions accounting for 80% of total supply chain costs and 75% of operational supply chain costs. (Harrison 2005; Wannenwetsch 2005)

The concept of the supply chain already emerged in the second half of the 20th century, when the cooperation between manufacturers, producers and suppliers of products and sellers developed. As mentioned above, this situation was reinforced in the 2000s precisely because of globalisation. With free movement, GDP increased, leading to a better quality of life and increased consumption. Supply chains are therefore of major importance for economic growth. (Poutvaara et al. 2019) An important part of SMC is therefore the continuity of supply chains, which ensures a continuous supply of goods and economic growth (Christopher & Peck, 2004). However, SCM is not only about managing the external factors of the firm, but is also strongly linked to managing the internal factors of the firm. According to Ivanov (2018), supply chain management can therefore be divided into two different categories: external, i.e. activities with suppliers and customers, and internal, i.e. the interaction of different departments within the company. These departments usually have conflicting interests that make supply chain management difficult to manage in the first place. This is why supply chain risk management has been developed, with the idea of preventing risks and minimising the risks that have already occurred.

According to Ivanov (2020), in the last decade, supply chain risks have increased due to epidemics and wars, which have dramatically increased the number of uncertainties and disruptions. Already in recent years, during the COVID-19 pandemic, disruptions occurred that crippled industries. Fortune (2020) mentions that the pandemic negatively affected more than 94% of the 1,000 largest companies. In addition, the pandemic caused particular

problems in supply chains and deliveries, which directly affected demand. These epidemics have also highlighted the ripple effect of risks on business survival. The pandemics have damaged the resilience and sustainability of SC. (Araz et al., 2020) Thus, in the recent past, many new reasons have emerged to study SCRM in more detail. (Richert & Dudek, 2023)

2.2 Supply Chain Risk Categories

One form of supply chain management is risk management. The cornerstone of risk management is therefore to identify different categories of risk, as different parts of the supply chain are exposed to different risks, the risk categories are not the same, and there are different mitigation methods for each risk. Supply chain risks cause problems in supply chains, usually caused by disruptions or delays that cause unexpected changes in flows (Christopher and Lee, 2004). The second definition, according to Zsidisin (2004), is the probability that inbound shipments are associated with hazardous events that may result in the buying firm being unable to meet customer demand or threaten the life and safety of customers. The main reason for delays in material flows is when a supplier is unable to respond to changes in demand. The solution to this is economic positioning and sizing. Supply chain disruptions are also very damaging for this reason as they are also very unpredictable.

The first risk to be addressed is systemic risk, or in other words, information flow risk (Tang and Musa, 2011), which is the risk that arises from the risks associated with information systems. The threat of systemic risk increases the greater the dependency on information risk. Addressing this risk is a key strategy for backup and recovery processes and related systems. (Mital et al., 2018) The technology risk mentioned by Treleve and Schweikhart (1988), can also be included in this risk category. This refers to all technological risk factors. Another risk to supply chains, according to Mital et al. (2018), is forecasting risk. This risk arises when there is a mismatch between forecast demand and actual market demand, causing problems in supply chains, and in such situations it is exacerbated when lead times

increase and demand becomes seasonal, compounded by large product ranges and short life cycles. The solution in these situations is responsive production and supply capacity.

The third risk is sourcing risk which is a direct consequence of forecasting risk. Sourcing costs will rise as a result of exchange rate fluctuations and price increases by suppliers. This is the risk of not being able to collect receivables. These two risks are so significant because they can undermine the financial performance of an organisation. It should also be noted that the increased risk that comes with supply chain disruptions can also cause problems in the form of long delivery times, in the form of stock outs. In addition, it can lead to an inability to meet customer demand and cost increases are also serious consequences of disruptions. (Mital et al., 2018)

In addition to the risks mentioned above, there is the uncertainty of supplier relationships, which according to Christopher and Peck (2004) is caused by variables such as supply, demand and environment. Suppliers are therefore subject to uncertainty, which affects supply chains. The dependence on the supplier mentioned by Wagner and Boden (2006) is also linked to this risk. This is also associated with potential increases in the transaction costs of supplier relationships. Risk categories in supply management include, according to Zsidisin (2004), price risk, which refers to price fluctuations. Inventory and scheduling risk, which reflects the risks to inventory and scheduling (Treleven and Schweikhart, 1988). Quality risk is also, according to Treleven and Schweikhart (1988), a category that refers to changes in the quality of products. Outsourcing can also be counted as a supply chain risk in its own right according to Lonsdale (1999), this is because if the production, or transportation of components is transferred to another firm, this can lead to a loss of the resources and capabilities that ensure the firm's competitiveness.

The final risk categories are Brand and Image Value Risk and Intellectual Property Risk. According to Koplin et al. (2007), poor quality, delayed deliveries and supply chain accountability problems can damage a firm's reputation and brand. Intellectual property risks

are seen by Norrman and Jansson (2004) as risks related to the loss of strategic knowledge in relationships and conflicts related to intellectual property rights, especially in technology cooperation. All the above risks are summarised in Table 1 below.

Supply chain risks can therefore be roughly divided into delays, disruptions, availability, price volatility, forecast inaccuracies, intellectual property infringements, system breakdowns, inventory problems, capacity problems, and procurement problems. These risks can be categorised as those resulting from fluctuations in supply and demand due to a wide range of factors such as the environment, organisation and supply chain variables. (Mitala,, Del Giudice and Papa, 2018) Supply chain disruptions must also be classified into internal and external disruptions. Therefore, there are also categories of disruptions such as demand-side disruptions, supply-side disruptions, regulatory, legislative and bureaucratic disruptions, infrastructure-related disruptions and catastrophic disruptions. The first two are supply and demand coordination risks that are internal to the supply chain. The other risks are external (Gaudenzi and Borghesi, 2006). Disruption risks and their sub-risk availability risk have been identified as particularly important risks, which are risk categories of particular relevance to this work. These risks have had a particular impact on supply chains on a global scale over the last few years, which makes it very important to study them. These risks are discussed in more detail in the following two sections.

Table 1: Supply Chain Risks

Supply chain risks:	Authors:
Disruption risk	Treleven and Schweikhart (1988), , Steele and Court (1996), Christopher and Peck (2004), Christopher and Lee (2004), Hallikas and Lintukangas (2016), Mital, Del Giudice and Papa (2018)
Quality risk	Treleven and Schweikhart (1988), Steele and Court (1996), Christopher and Peck (2004), Hallikas and Lintukangas (2016)
Communication and information delivery risks and related system risk	Tang and Musa (2011), Hallikas and Lintukangas (2016), Mital, Del Giudice and Papa (2018)
Risks in deliveries and lead time, also forecast risk/ inaccuracy of forecasts	Steele and Court (1996), Tang and Musa (2011), Hallikas and Lintukangas (2016), Mital, Del Giudice and Papa (2018)
Intellectual property infringement risk	Lonsdale (1999), Norrman and Jansson (2004), Hallikas and Lintukangas (2016), Mital, Del Giudice and Papa (2018)
Dependency risk (on suppliers)	Koplin et al. (2007), Christopher et al. (2011), Hallikas and Lintukangas (2016)
Inventory related risk	Zsidisin et al. (2000), Hallikas and Lintukangas (2016), Mital, Del Giudice and Papa (2018)
Outsourcing related risk	Lonsdale (1999), Hallikas and Lintukangas (2016), Mital, Del Giudice and Papa (2018)
Availability risk	Treleven and Schweikhart (1988), Steele and Court (1996), Christopher and Peck (2004), Christopher and Lee (2004), Hallikas and Lintukangas (2016)
Reputation and brand related risks	Koplin et al. (2007), Christopher et al. (2011), Hallikas and Lintukangas (2016)
Risks associated with price volatility	Zsidisin (2004), Hallikas and Lintukangas (2016)

2.2.1 Disruption Risks

Effectively managing the risk of disruption hinges on the identification of sources and vulnerabilities associated with various risks. Diverse origins contribute to disruption risks, as highlighted by Kleindorfer and Saad (2005), with operational contingencies ranking prominently among them. Operational contingencies encompass equipment failures and system breakdowns, exemplified by occurrences like power outages, as evidenced in the North-East blackout of 2003. Additionally, abrupt interruptions in the supply chain, stemming from factors such as supplier closures, bankruptcies, and labor strikes, fall under this category.

Natural hazards constitute another significant category of disruption risks, encompassing events like earthquakes, hurricanes, and storms. These natural phenomena can inflict severe losses on industries, leading to substantial economic disruption. The repercussions of such events reverberate through supply chains in the form of shock waves, as illustrated by the impactful Kobe earthquake in Japan in 1995, as cited by Kleindorfer and Saad (2005), which significantly disrupted shipping operations.

The third category encompasses man-made threats, including terrorism, political instability, and warfare. Exemplifying this type of disruption are events like the 2001 attack on the World Trade Center and the ongoing Russo-Ukrainian war in Ukraine. Kleindorfer and Saad (2005) note a substantial rise in the prevalence of this category in recent years, with profound implications for supply chains necessitating further investigation. As supply chains extend in length and complexity, political instability exerts a considerable impact on a substantial portion of global supply chains (Kleindorfer and Van Wassenhove, 2004).

In navigating these multifaceted disruption risks, it becomes paramount for organizations to not only recognize the diverse sources but also to develop robust strategies that address each

category's unique challenges. This proactive approach ensures a comprehensive and resilient risk management framework capable of safeguarding supply chains from the myriad threats posed by operational contingencies, natural hazards, and man-made disruptions.

2.2.2 Availability Risks

Disruption risks are intricately tied to another risk known as availability risk (Steele and Court, 1996). Availability issues stem from disruption risks, where disasters and political upheavals can give rise to production challenges or government-imposed sanctions. These issues ultimately manifest in supply chains, causing products and raw materials to fall short in reaching suppliers in the affected countries, termed as supply chain availability risk. Hendricks and Singhal (2003) assert that supply chain disruptions lead to a reduction in shareholder wealth, emphasizing the imperative for firms to promptly implement corrective measures.

Inman and Bhaskaran (2019) underscore supply risk and its closely associated availability risk as the most significant concerns in their paper. While supply risks are commonplace in companies and frequently occur, they often go unnoticed due to their perceived lesser significance compared to business failure or intellectual property theft. However, on a broader scale, such disruptions can have a substantial impact on a company's stock and, consequently, its sales (Thun and Hoenig, 2011). The complexity of a company's production, requiring numerous components simultaneously, amplifies the risks to availability and supply (Inman and Bhaskaran, 2019).

Supply disruptions also contribute to spare parts shortages. Lin, Huang, Liao, and Yeh (2017) define delivery risk as the failure of ordered products to arrive within a specified time frame, potentially preventing delivery altogether. Late orders, resulting from supply disruptions, can hinder a company's ability to sell products if there are insufficient components in backup stock. Hendricks and Singhal (2003) identify the lack of parts as the primary cause of supply chain conflicts. Another form of supply disruption is time delays,

with delivery delays deemed the most severe in terms of probability and impact (Vilko and Hallikas, 2012). The risk of supply failure is also acknowledged as a distinct risk type (Dupont, Bernard, Hamdi, and Masmoudi, 2018). Supply chain disruptions are pervasive across all supply chains, with broader supply chains presenting greater challenges and more severe disruptions, leading to higher vulnerability. Extended supply chains not only heighten the risk of supply disruption but also escalate logistics and coordination costs (Demeter, 2014). The complexity of the supply base and unreliable lead times further exacerbate these risks (Brandon-Jones, Squire, and Van Rossenberg, 2015; Mehrjoo and Pasek, 2016).

Brandon-Jones, Squire, and Van Rossenberg (2015) highlight in their work that transparency and flexible resources can mitigate the impact of risk. Shorter supply chains significantly reduce disruptions (Inman and Blumenfeld, 2014). Additionally, Co, David, Feng, and Patuwo (2012) discovered that long lead times between intercontinental players contribute to increased inventories and the bullwhip phenomenon. Hammami, Frein, and Bahli (2017) propose the establishment of guaranteed delivery times as another risk-reducing factor, prompting manufacturers and suppliers to position themselves closer to demand.

Table 2: Disruption and Availability Risks

Disruption risks:	Availability risks:
Operational uncertainties: • Equipment and system failures • Power outages (Kleindorfer and Saad, 2005)	**Component Shortages:** • Certain items may experience complete delivery failures (Lin, Huang, Liao, and Yeh, 2017)
Natural disasters: • Earthquakes, hurricanes, and storms pose significant risks (Kleindorfer and Saad, 2005)	**Extended and Unreliable Delivery Times/Time Delays:** • Delivery timeframes are prolonged, leading to potential disruptions (Vilko and Hallikas, 2012; Brandon-Jones, Squire, and Van Rossenberg, 2015; Mehrjoo and Pasek, 2016)
Man-made threats: • Terrorism, political instability, and wars are factors to consider (Kleindorfer and Saad, 2005; Kleindorfer and Van Wassenhove, 2004)	**Delivery Failures:** • Inability to successfully deliver products to the intended destination (Dupont, Bernard, Hamdi, and Masmoudi, 2018)
	Logistical Disruptions: • Shipping Problems: Challenges in the transportation process affecting the timely delivery of goods • Availability Issues Due to Logistics: Disruptions arising from logistical complications impacting the availability of products (Demeter, 2014; Dupont, Bernard, Hamdi, and Masmoudi, 2018)

2.3 Risk Management

The first step is to define what the risk is. According to Manuj & Mentzer (2008), risks are the things that keep us from the perfect path and the perfect outcome. Another definition of risk might be "unintended outcomes". So risks are divided into two components. These are the potential losses and the probability of those losses (Manuj & Mentzer, 2008). As mentioned, supply chain risk management has become essential to supply chain management. Narasimhan & Talluri (2009) cite the importance of this topic as having become particularly important due to the increasing globalisation of markets, growing interdependence of companies and increasing outsourcing. Supplier networks are becoming increasingly complex, so supply chain management and risk management in these networks have become one of the cornerstones of procurement. Moreover, due to increased innovation, dependency on the competitive advantages of supply networks has increased. There is increasing cooperation with international supplier partners. (Lee, 2002) As Ohlson (2014) mentions, Supply chain risk management (SCRM) is vital because of the scale of disruption. Countries' supply chains require reliable supplies of inputs to avoid, for example, payment defaults and the resulting major disruptions such as layoffs and stoppages in production. SCRM involves a process of risk identification, risk assessment, risk avoidance and risk mitigation. This process, therefore, allows the design of effective strategies and solutions to strengthen and manage risks in global supply chains. Proactively addressing changing supply chain risks and vulnerabilities can secure supply chain systems. According to Rajesh, Ravi and Venkata (2015), risks can be classified as internal and external to the supply chain, short term and long term, low impact and high impact on supply chains. These terms and concepts are explored in more detail in the Master's thesis itself.

In their text, El Baz a & Ruel (2021) mention that, according to current research, supply chain risks can be divided into operational and disruption risks. Operational risks are the usual risks inherent in supply chain operations, including lead times and fluctuations in demand (Hosseini et al., 2019). On the other hand, disruptive risks occur much less frequently, i.e. their frequency is low, and their impact is much more significant than that of operational risks. Examples of disruptive risks are disasters such as natural disasters, floods,

hurricanes and the like. They also include man-made disasters such as terrorist attacks, wars and nuclear meltdowns, and economic crises. (Ohlson, 2014)

It is essential to analyse risk management through models and the process. Therefore, the risk management process mentioned above is seen as a critical cornerstone of risk management in supply chain management. This section briefly explains the main elements of the process. This process is divided into risk identification, risk assessment, risk avoidance and reduction. In his text, Olson (2014) mentions that risk identification is strongly linked to the abovementioned division into operational and disruptive risks. Often quantitative analyses and methods focus on operational risks. Disruptive risks are more difficult to predict and, therefore, more challenging to model. Planning and response tend to be qualitative. Considering improbable circumstances can be seen as particularly important in risk management. Business involves great uncertainty, such as the problem of data availability and the consideration of several conflicting factors. Estimating specific factors such as probability is even more difficult in these situations, which is why reliable strategies attract risk management. These strategies often create effective responses to many different situations. These models and strategies can be both qualitative and quantitative. The strategy is valid if the company can continue its operations despite significant disruptions. (Olson, 2014)

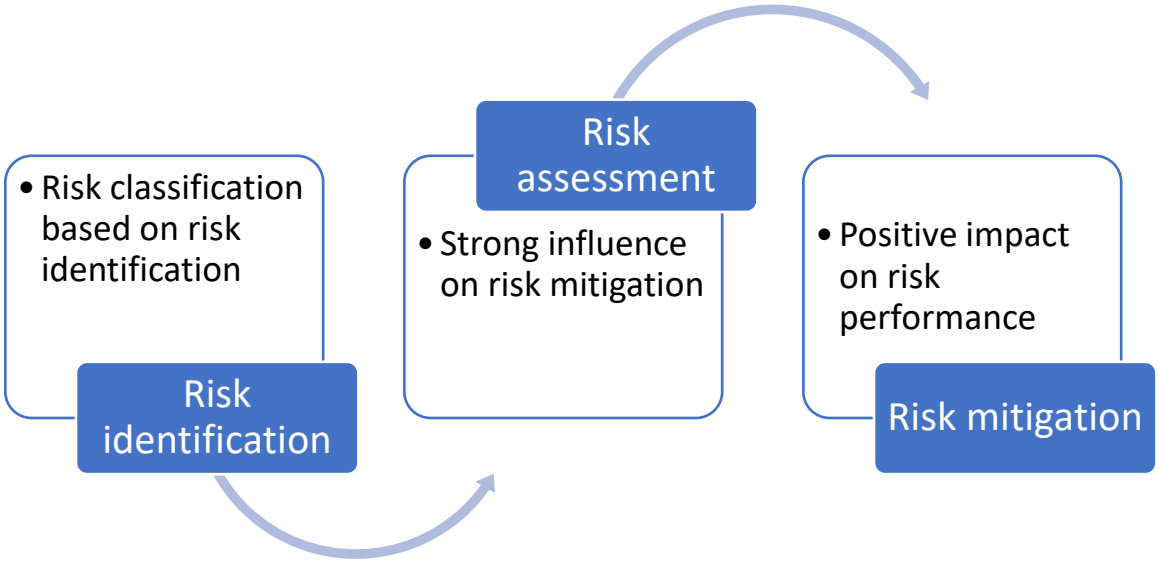

Figure 2: Conceptual Model of Supply Risk Management (Kern, Moser, Hartmann, and Moder, 2012)

2.3.1 Risk Identification

As mentioned above, risk management has become an increasingly important part of SCM. Recent studies underline the crucial importance of risk management. As global supply chains become more complex, a holistic approach to risk identification is crucial. Unlike domestic supply chains, global supply chains require specific risk identification strategies. Therefore, the ability to identify different types of risks is crucial for the effective management and planning of global supply chains. (Ivanov, 2021) This section discusses the first of the three main types of risk management, risk identification.

Risk identification is essential in risk management, especially in supply chain management and organizational resilience. It is the basic process of identifying potential risks and vulnerabilities that could adversely affect the organization's operations, performance and strategic objectives. Effective risk identification must be considered, as it is the cornerstone

on which subsequent risk assessment, mitigation and response strategies are based at this stage. (Ivanov, 2021)

Over the years, the scientific debate on risk identification has produced several significant results and methodological frameworks (Dina Neigera, Kristian Rotarua, Leonid Churilov, 2009). Researchers have delved into the details of this process, seeking to outline comprehensive risk frameworks and clarify the complex factors that influence risk identification. Risk classification, which is intrinsically linked to risk identification, has also received much scholarly attention in recent decades. (Neigera et al., 2009) Miller's taxonomy, which classifies uncertainties into three general dimensions - general environment, industry and firm - provides the basic structure for risk classification. On the other hand, Ganesh and Kalpana (2022) refine the risk classification by defining five primary risk categories: technological, economic, financial, performance and legal/regulatory. The financial category is central to this classification system and subdivided into foreign exchange risk, a sub-category of risk requiring specific attention and risk management strategies.

A comprehensive risk classification is based on its profound impact on subsequent risk assessment and management measures. A comprehensive and accurate classification allows organizations to distinguish between differing risks, enabling a judicious choice of risk management methods tailored to the specific nature of each identified risk (Ganesh & Kalpana, 2022). Empirical evidence confirms the usefulness of such distinctions, as evidenced by the extensive use of derivatives to hedge transaction risks, balance sheet risk management to mitigate translation risks, and strategies to manage competitive risks. In addition to risk identification, subsequent stages of risk management have recognized that effective risk classification is essential to risk assessment (Neiger et al., 2009). (Neiger et al., 2009) Distinguishing between different risk categories is an essential basis for comprehensive risk assessment, in line with the arguments of Chopra and Sodhi (2004), who advocate a holistic understanding of risks, their typology and the conditions that give rise to them. The academic debate stresses the importance of developing dynamic risk models considering evolving managerial perceptions and industry-specific characteristics

determining an organization's risk exposure. However, this work has already identified the category of risks to be studied, namely disruption and availability risks, and therefore, this section has been addressed in advance.

In addition to risk identification, the subsequent stages of risk management have recognized the intrinsic value of effective risk classification in risk assessment. Distinguishing between different risk categories is a necessary basis for a comprehensive risk assessment, in line with the arguments of Chopra and Sodhi (2004), who advocate a holistic understanding of risks, their typology and the conditions that give rise to them. The academic debate stresses the importance of developing dynamic risk models that consider evolving managerial perceptions and industry-specific characteristics determining an organization's risk exposure.

2.3.2 Risk Assessment

After risk identification, the second step in SCRM is risk assessment. Kern, Moser, Hartmann and Moder (2012) mention in their text that assessment can be seen as an essential part of risk management and strongly impacts risk mitigation. The literature mentions that assessment consists of a probability assessment and an assessment of the impact if a risk event occurs. Therefore, the primary purpose of risk assessment is to provide in-depth information on the risks identified to avoid and reduce the probability and impact of the risk in question as comprehensively and as well as possible. Another critical element is to accept that the risk will occur and thus create contingency plans in case the risk reduction strategy does not work. (Kern, Moser, Hartmann and Moder, 2012)

As mentioned above, considerable factors in the risk assessment process can lead to a particular risk materialising. This step provides information on the drivers of the risk and the key risks. It is crucial to consider the relationship between the risks and these triggers. (Kleindorfer and Saad, 2005) Thus, according to Hendricks and Singhal (2003), disruption is affected by how quickly the risk develops and how quickly the risk event persists. Risk outcomes must, therefore, be classified according to the risks identified and ranked in order

of priority. Graphical observation tools are available for this purpose (Hallikas, Virolainen and Tuominen, 2002). These tools can also be used to determine how severe the risk is; one way of measuring this is the risk assessment matrix, which will be discussed later in the literature review. Therefore, with a good understanding of any identified risk, a risk assessment can trigger comprehensive mitigation measures to prevent events that have already occurred or will occur. Therefore, a very accurate and careful risk assessment is vital to ensure the right actions are taken. (Kern et al.,2012)

2.3.3 Risk Mitigation

The third stage in the risk management process involves risk mitigation, a crucial step to reduce potential threats. Effective risk reduction relies on the comprehensive information gathered in the preceding phases of risk management. Identifying and defining risks accurately is imperative for implementing appropriate countermeasures. Risk mitigation can be categorized into two distinct phases: classical mitigation strategies, applied proactively before a risk event occurs, and contingency plans, enacted reactively after a risk event has transpired (Kern et al., 2012).

While classical strategies are preferable, the latter contingency plans are often less desirable, as they signify that a risk event has negatively impacted the company's operations. Nonetheless, both strategies are integral to a robust risk management framework. Each identified risk necessitates the development of a well-thought-out mitigation strategy. Consequently, as emphasized by Chopra et al. (2007), ongoing monitoring after the three-step process is imperative for refining and adjusting risk management strategies.

Prevention is underscored as a more critical aspect of risk management than aftercare (Kleindorfer & Saad, 2005), prioritizing addressing urgent risks promptly. Using a risk

assessment matrix aids in swiftly identifying high-risk events, facilitating timely intervention and more effective prevention. Therefore, maintaining a heightened focus on risk management throughout the company is essential (Zsidisin et al., 2004).

For effective risk mitigation in supply chains, seamless collaboration among all company functions and the inclusion of suppliers in the process are paramount. Berg, Knudsen, and Norrman (2008) highlight the pivotal role of top management support, emphasizing its contribution to holistic thinking, collaborative decision-making, and, notably, execution in this process. Fostering a culture of vigilant risk management across the organization is imperative for sustained success.

Mitigation measures are designed to decrease the likelihood of risks occurring and reduce actual risks post-occurrence (Tomlin, 2006). Given the dynamic nature of risks, there is no one-size-fits-all strategy, and constant development of new approaches is essential for preventing and managing emerging risks. Among the three steps in risk management, risk reduction holds the most significant impact, directly influencing risk outcomes. In contrast, other steps contribute to risk reduction but necessitate concrete actions to prevent risks proactively. Kern et al. (2012) succinctly capture this concept, emphasizing the positive influence of risk mitigation on supply chain performance.

In his work, Olson (2014) outlines vital risk mitigation methods for supply chain risk management, stressing the importance of strategic and tactical considerations. Strategic aspects, such as supply chain network design, play a role in managing supply risks by identifying alternative sources for emergencies and diversifying product ranges for protection against product-specific risks. Improved industry visibility enhances risk management effectiveness. At the tactical level, decisions related to supplier selection, order allocation, time management, market and product demand, and collaborative planning contribute significantly to risk management.

Various tools have been developed to mitigate and prevent supply chain risks. Inman and Bhaskaran (2019) highlight the potential of investments in information technology, process design, and management controls for risk prevention or mitigation. As discussed earlier, extending supply chains amplifies risks, emphasizing the importance of keeping supply chains as concise as possible. Longer supply chains introduce delays, increasing the risk of availability issues influenced by transportation modes, sorting points, congestion, weather conditions, labour strikes, political unrest, and piracy. Administrative measures are crucial for addressing these risks, requiring careful consideration of the most suitable measures. Effective management and meticulous supply chain planning emerge as the primary solutions, with considerations tailored to the specific circumstances of each company, including supplier locations, product delivery times, and chosen supply modes.

In terms of technology, information systems play a vital role; the availability of goods from the same country or neighbouring countries and the transparency of supply chains can be easily examined using systems. One is the Kanban system, which is relatively inexpensive. However, this transparency problem becomes more complex the longer the supply chain becomes and requires an expensive visibility system. Moreover, introducing such a system involves additional work, as the more steps in the supply chain, the more work it requires. Therefore, each company representative in the supply chain must update the system with accurate, timely information on deliveries for the system to work. This ultimately requires more investment, human resources and training. (Inman and Bhaskaran, 2019)

Price is a critical factor in supply chain management, exerting significant influence even when opting for a shorter supply chain is deemed advantageous. The decision-making process often hinges on price considerations, prompting the selection of longer supply chains. However, as highlighted earlier, this inclination introduces heightened risks, becoming a focal point in the procurement process. Furthermore, inventory management is a strategic tool to address various challenges, including those associated with long-distance deliveries. Despite its mitigating potential, the delivery time can extend over weeks to months, contingent on the availability of goods and production timelines. This, in turn, gives

rise to the predicament of managing buffer stock, with the magnitude increasing proportionally to the delivery distance.

To navigate the intricacies of goods availability, a common practice involves assessing the current stock situation and estimating its longevity. If the existing stock is insufficient to cover the delivery timeframe, organizations resort to costly interventions, such as expedited deliveries. Typically conducted by air, these special deliveries, as outlined by Inman and Bhaskaran (2019), become a recourse when standard measures fall short.

A pivotal strategy for mitigating availability risk and minimizing disruptions is implementing the Just-In-Time Replenishment strategy. (Mitala, Del Giudiceb, and Papa, 2018) This approach prioritizes streamlining the supplier base and fostering long-term partnerships. By reducing the number of suppliers, coordination efforts for timely deliveries are streamlined, leading to enhanced quality performance. Opting for significant procurement volumes from a single supplier offers additional benefits, including favourable contractual terms such as volume discounts and flexible payment options. The economies of scale, coupled with a commitment to quality improvement, are highlighted as critical advantages of cultivating enduring supplier relationships, as emphasized by Tang and Musa (2011) in their study.

Table 3: Availability Risk Mitigation in General Supply Chains

Risk mitigation strategy:	Authors:
Senior Management Support: • Emphasizing risk management • Facilitating joint decision-making and implementation	Berg, Knudsen and Norrman (2008)
Supply Chain Optimization: • Network planning for enhanced supply risk management	Tang and Musa (2011), Olson (2014),
Diversification of Supply Sources	Olson (2014)
Product and Supply Range: • Diversification for a wider product range	Olson (2014)
Supply Chain Transparency: • Investments in IT, process design, and management control • Improving transparency	Olson (2014), Inman and Bhaskaran (2019)
Supply Chain Efficiency: • Planning and possibly shortening supply chain length	Inman and Bhaskaran (2019)
Implementation of the Just-In-Time Replenishment Strategy: Significantly prioritizing the rationalization of the product supply base and fostering sustainable collaborative partnerships	Mitala, Del Giudiceb and Papa (2018)
Inventory Management: • Accurate control and efficient management	Inman and Bhaskaran (2019)

2.3.4 Risk Mapping

Effective risk management hinges on the continual identification and analysis of potential risks. By giving careful attention to these risks, their prediction and prevention become more feasible, and in ideal scenarios, they can even be anticipated. Central to risk management is the process of risk mapping, which serves as a cornerstone in understanding and addressing potential threats. In this section, our focus will be on the tools used for risk mapping, with a particular emphasis on the risk assessment matrix—a primary model for gauging the

probability and severity of risks. This model enables the assessment of the seriousness of various risk categories. As previously mentioned, risks can be categorized into distinct types, particularly within supply chains. Examples include technology risks, market risks, organizational risks, environmental risks, supplier-related risks, and cost risks (Gurtu and Jestin 2021; Arabshahi and Hamed 2019). In the context of supply chains, our primary focus is on the examination of supply disruption, specifically the risk associated with availability.

Richert & Dudek (2023) propose a categorization of risk areas into five distinct categories: Very low risk events: Events that can be swiftly eliminated and have no lasting impact. Low risk/rare events: Events that impact supply chains but with a relatively small overall impact. Medium risk events: Events with a material impact on supply chains. High risk events: Events with serious consequences, affecting the timely execution of supply chains. These could result from partner departures, accidents, staff shortages, scheduling problems, and other challenges hindering dispatch and timely delivery or manufacturing. Catastrophic risk events: Events leading to a complete disruption of the supply chain, such as fund withholding, partner departures, natural disasters, or external factors that paralyze the supply chain. Risks can be systematically mapped based on their likelihood of occurrence and severity. A numerical representation is employed within the risk mapping system to quantify the probability of each risk, as depicted in Table 4. 1-3 indicates low severity points, 4-6 indicates moderate severity, 8-12 indicate medium severity, and 15-25 indicates high severity for frequent incidents. Immediate attention is crucial for high severity points, as they significantly impact supply chains and availability (Richert & Dudek, 2023). This model serves as a powerful tool for pinpointing the key factors contributing to availability risk and assessing their impact on supply chains. By leveraging the insights derived from this analysis, potential strategies to proactively mitigate the most critical disruptions can be explored. The significance of this model is underscored in the empirical section of the paper, where it plays a central role in both the formulation and examination of findings.

Table 4: Risk Assessment Matrix (Richert & Dudek, 2023)

Likelihood:	Consequence Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost certain 5	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
Likely 4	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
Possible 3	Low 3	Moderate 6	High 9	High 12	Extreme 15
Unlikely 2	Low 2	Moderate 4	Moderate 6	High 8	High 10
Rare 1	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

2.3.1 Gaps and Challenges in Managing Disruption and Availability Risks

As Inman and Bhaskaran (2019) mentioned in their article, the challenge is the uniqueness of each delivery and design. Every risk management related project is different and this creates problems in supply chain management, so there is no one right way to minimise risk that works for all companies in the world. This is why there is so much research to be done on the subject, as risk is a sum of a company's location, size, storage and the sum of its assets. However, it can be said that there are ways in the literature to influence risk in supply chains, we just need to see if they work in the electrical goods sector. The situation therefore needs to be examined on an industry-specific basis, which also complicates this study.

3 Research Methodology

This section delves into the empirical research methodology and the associated data. The research adopts qualitative research methods, a multifaceted domain characterized by interpretative approaches (Metsämuuronen, 2005, p. 198). Qualitative research, inherently intricate to precisely define, encompasses various interpretative methods, deploying diverse approaches and techniques for both data collection and analysis (Hirsjärvi et al., 2004, pp. 151-157).

This study focuses on electrical supply companies and, by extension, their supply chains, given that many of their transactions involve stock purchases. This dynamic significantly influences the supply chains of firms, with a notable increase in supply chain failures observed in more internationally active enterprises (Gurnani et al., 2012). The study particularly scrutinizes the critical impact of disruptions on commodity supply chains.

The chosen data collection strategy is a case study, concentrating on the specific circumstances of the target company: a wholesale entity in the electrical goods sector, and delving into the intricacies of its suppliers. Importantly, this work centers solely on the supply chains of these specific companies, rather than attempting to generalize findings to all supply chains within the broader electrical goods sector.

3.1 Data Collection

The study employs interviews as its primary data collection method, a widely utilized and flexible approach suitable for diverse research objectives (Hirsjärvi & Hurme, 2001, p. 34). Metsämuuros (2005, 226) underscores the significance of interviews as a data collection tool, categorizing them into structured, semi-structured, and open-ended types. Moreover,

interviews can be classified into individual and group formats based on the number of participants (Metsämuuronen, 2005).

In this study, a semi-structured interview method is adopted. Individual interviews are conducted with each target company, preceded by the distribution of a predetermined set of questions encompassing four main categories and 14 sub-questions to each company in advance. Before the semi-structured interviews, a risk assessment questionnaire, evaluating the likelihood and impact of specified risks, is administered to each interviewee. This assessment contributes to risk mapping, a crucial aspect of empirical analysis. The questions are tailored to address sectoral factors, encountered risks, response models, and mitigation strategies employed by the companies.

The main target company's perspective, as a wholesaler, is complemented by the suppliers' views, offering insights into diverse supply chain situations. While the primary focus is on the wholesaler's viewpoint, the suppliers' perspectives are deemed vital due to potential consequences distinct from the main target company. This comprehensive approach aims to provide insights into supply chains, buyer-supplier relationships, and potential avenues for enhancing cooperation.

During the interviews, flexibility is maintained, allowing interviewees to navigate through the questions, and additional queries can be posed. The interviews evaluate the overall state of the company's supply chain, potential availability risks, risk categories, management models, and preventive measures against disruptions. A detailed risk mapping encompasses the identification of risks in procurement, operational, and strategic activities, gauging severity and likelihood. The empirical section relies solely on the perspectives of the interviewed professionals.

Prepared questions guide the interviewees and afford them time for preparation. Post-interview, further inquiries can be addressed via email. The chosen method of analysis for this study is content analysis, wherein interview questions are categorized thematically and analyzed based on their content. The empirical section of the study will also involve a thematic discussion of the questions, providing a nuanced understanding of the gathered information.

3.2 Data Analysis

The method of analysis used in this thesis is content analysis. The content analysis aims to gain insight into the subject of the research. In other words, it aims to obtain a concise description without losing the informational value of the data (Metsämuuronen, 2005, p. 233). It is a scientific tool for drawing reproducible and inferable conclusions from text or data to their contexts of use. Content analysis as a research technique offers insights increases understanding of phenomena and provides comprehensive information for practical action. The positive aspects of the technique are that it is reliable, the idea being that the technique leads to reproducible results. So, the repeatability must be the same even if the circumstances change. (Krippendorff, 2019)

Content analysis can be summarised in three definitions. Definitions where content is considered to be contained in the text, definitions where content is considered to be a property of the source of the text, and definitions where content emerges from the researcher's analysis of the text in relation to a particular context. Each method has its style of conceptualising the analysis and the methods of analysis. (Krippendorff, 2019)

This work analyses content through videos, discussions and text data. These data will be compared with each other. Secondary data from the literature will be compared with data from interviews. In addition, numerical data will be collected from the interviews for a risk assessment matrix to be compared with previous literature. The work will, therefore, use a number of different data sources and analyse them using this method of analysis.

3.3 Case Study Selection and Research Instruments

A case study involves an in-depth examination of a singular event or a specific instance, as highlighted by Metsämuuronen (2005, p. 205). In approaching a case study, researchers must consider two distinct starting points. First, the researcher may have a specific case of interest. In such cases, the researcher, based on the unique characteristics of this chosen case, makes deliberate choices regarding the manner and conceptual frameworks through which the case will be scrutinized. Alternatively, the researcher might be intrigued by a particular phenomenon and possess a comprehensive understanding of all its fundamental concepts. (Metsämuuronen, 2005)

Given that not all the key concepts are known for the current study, the chosen approach aligns with the first option. The research focuses on a specific case, and decisions regarding the analytical framework and conceptual lenses are made based on the distinct attributes of that case. The chosen method of analysis for this study is content analysis.

3.4 Case Companies

The empirical segment of this study draws upon interviews conducted with companies engaged in the sale of electrical equipment or associated components. Specifically, two interviews were undertaken with the primary company, denoted as A, and an additional two interviews were conducted with its suppliers, identified as B and C. The aim was to scrutinize the supply chain dynamics within the sector. For confidentiality reasons, the companies are referred to as A, B, and C, with their actual names undisclosed.

Company A operates as an international wholesaler specializing in B2B sales of electrical, telecommunications, and automation products. Its clientele includes contractors, industrial customers, and electricity distribution companies. Meanwhile, Company B, a Finnish entity, specializes in the production of cable tray systems, offering a diverse range of shelving products such as ladder racks, plate racks, wire racks, lighting rails, cable trays, and socket poles. The company's manufacturing processes heavily rely on crucial raw materials such as steel and aluminum. On the other hand, Company C is an international player focused on digital automation and energy management. It integrates energy technologies, automation, software, and related services. Table 5 below provides a detailed description of each company and their respective representatives.

The analysis of these companies centers around the B2B market, as all the companies under consideration operate within this sphere. While the primary company has a global presence, this study specifically examines its Finnish operations and supply chains. Similarly, the analysis of suppliers is primarily concentrated on organizations within Finland and the Nordic countries. The interviews were conducted with key personnel, including the procurement director and procurement manager of Company A, the procurement manager of Company B, and the logistics director of Company C. This approach ensures a comprehensive understanding of the collaborative dynamics in the supply chain

Table 5: Companies and Representatives

Company:	Representatives:
Company A: Wholesaler of electrical equipment	**Interview 1:** Procurement Director
	Interview 2: Procurement Manager
Company B (supplier): Manufacture of cable tray systems	**Interview 3:** Procurement Manager
Company C (supplier): Specialising in digital automation and energy management	**Interview 4:** Logistics Director

3.5 Limitations of the Study

The work is based on interviews with only one electrical supply chain and two of its suppliers. This gives only a limited insight into supply chain management and its risk management. Furthermore, the work only involves electrical equipment companies and their supply chains. Different sectors may have quite different disruptions and problems. The b2c view is also not considered, as the chain is only between companies, and the end users are also construction and contracting companies, not individuals. It is also important to note that the work specialises in managing named risks in the area of disruption risks and, in particular, availability; other forms of risk management are not considered in the empirical section. These situations, therefore, have a significant impact on the scope and validity of the work. The work is, therefore, a relatively limited overview of the supply chain, as the suppliers' suppliers were not interviewed, making it difficult to get an overall view of the supply chain. However, the critical question of availability will be answered, as risk mitigation is also practised on a company-by-company basis.

4 Risk Management in an Electrical Equipment Sector Chain

This section primarily comprises insights gathered from interviews, focusing on the supply chain disruptions faced by target companies A, B, and C. It integrates data from secondary sources and the theoretical framework previously discussed. The analysis involves two distinct supply chain scenarios: one for companies B and C, which specialize in different components, and another for wholesaler A, combining both supply chains.

The exploration centers on the assessment of availability risks within these supply chains, delving into disruption risks and corresponding risk management strategies. The chapter unfolds across four sections: a detailed examination of supply chain challenges associated with availability risk, presentation of risk mapping results, delineation of short and long-term solutions tailored to the circumstances of the target companies in the electricity equipment sector, and a comprehensive discussion on effective risk management models designed to preempt disruptions and availability risks.

4.1 B2B Distribution of Electrical Products

This work needs to present the market for electrical equipment. According to NASDAQ OMX (2021), this is a market consisting of the sale of products that generate, distribute and use electrical energy. Organisations, individual traders and partnerships carry out this activity. This market can be broadly divided into electric lighting equipment, household appliances, electricity generation, transmission and control, batteries, and wires and cables. (NASDAQ OMX, 2021) The electrical equipment market can be divided into regions at the global level. The Asia-Pacific electricity market is the largest of these regions, accounting for around 45% of the industry market in 2020. Another primary market is Western Europe, which is the second largest market, according to NASDAQ OMX (2021). This region accounts for around 22% of the total. The smallest market in the electricity equipment sector is in Africa.

The electrical goods sector is constantly innovating, as electronics are constantly evolving. An excellent example of this is light bulbs and the development of new smart devices and sockets, which are constantly innovating. According to NASDAQ OMX (2021), sockets now have USB plugs that charge any device. The pace of innovation and technological development is increasing the pressure on the sector to evolve continuously. With consumers and business users constantly having to upgrade equipment and components, the market has much potential. As a result of this continuous evolution, the demand for electronic equipment is increasing and will eventually put pressure on supply chains. The COVID-19 pandemic has also had a significant impact on this sector. The disease outbreak in 2020 has dampened the sector's market, with production of electrical appliances declining due to disruptions to supply chains. As a result of the trade restriction, consumption declined globally. This has remained partly unchanged as new sanctions have emerged following the Russian war. NASDAQ OMX (2021)

4.1.1 Current State of Electrical Equipment Sector Supply Chains

The empirical part of the thesis consists of interviews with electrical component companies. It is, therefore, crucial to examine the current state of the supply chains of electrical components and the impact of disruption risk and availability risk on this sector in particular. Like other commodity supply chains, the supply chains for electrical components are a complex network of suppliers and manufacturers specialising in producing, transporting and selling electrical goods. The supply chains for electrical components have also been affected by the COVID-19 pandemic and various embargoes, which have caused severe problems in the supply chains, especially disruption risks. (BayPower, 2022) Knox (2023) also mentions in their text that the war in Ukraine has had a severe impact on the current situation of the electrical supply chains after the pandemic. Supply problems have continued, and prices have risen due to availability challenges. The deterioration of relations between the US and China has also exacerbated the supply chain situation. This is because China is the primary source of many components at a global level. Much has happened in the last few years in international supply chains; shortages of raw materials, order backlogs, congested transport

channels and labour shortages have also been significant problems in this sector. On a global scale, this has also led to component price increases of close to 20% in 2022, according to BayPower (2022), and even more for some components. Further, waiting times have increased as a result of disruptions to availability. BayPower (2022) mentions that this would have affected all product types, be it circuit breakers, motor controllers, transformers, isolators, switches or other components.

It is important to know what the electrical component supply chains are to identify disruption risks and precise availability problems. This network works together to supply the electrical components needed to manufacture electrical products. The supply chain includes mining, raw material suppliers, component manufacturers, assemblers, distributors, and other manufacturers who assemble machines or software. Several suppliers are in this intermediate chain. (BayPower, 2022) This role is essential for managing inventory levels. However, as a rule, this work will focus only on suppliers and distributors. Supply chains have been under regular pressure at the global level, especially since 2020, when the COVID-19 pandemic broke out and caused problems in the electrical components sector. The problems mentioned include raw material shortages, labour shortages, courier overloads and order backlogs already partly mentioned above. BayPower (2022) mentions that at a global level, miners faced labour shortages, which have affected other companies in the supply chain, for example, by increasing component prices. As a result, there have also been problems with availability as not all components have been available due to high demand.

In 2023, the situation has also changed slightly compared to previous years. Although the electricity price index has stabilised in the third quarter of 2022, the supply of specific components has been scarce. According to Knox (2023), these include switchgear and the supply of electrical switchboards. The price index is expected to rise by 1-3% and then stabilise. However, with last year's price increase, copper scarcity has also contributed to the supply shortage of switchgear, circuit breakers, and panels. Thus, there are still shortages of critical supplies globally, affecting availability and causing many disruptions, project delays, price increases and other supply chain disruptions. According to Knox (2023), small

entrepreneurs and contractors at the end of the supply chains who have less purchasing power will be particularly affected.

4.1 Problems Encountered in Target Companies

As shown in the theoretical part, the supply chains in the electrical goods sector have also experienced many supply chain problems in recent years. Knox (2023) mentioned in his text that potential problems in the electrical supply sector have arisen in the last year due to component availability problems, product price increases, project delays, price increases and other supply chain disruptions. However, these all stem from problems with raw material availability at the upstream end of supply chains, as well as factors affecting supply chain availability in general, as the fewer components are available, the more desirable they become, and prices rise very strongly due to demand. The Russo-Ukraine war has also impacted these disruption risks and their availability problems. Therefore, disruptions must be strongly mirrored in recent years, as well as the pandemics, wars, and natural phenomena that caused disruptions in supply chains.

Disruptive events must be strongly mirrored in recent years to the pandemics, wars and natural phenomena caused by these disruptions. When the COVID-19 pandemic started, the worst disruption to availability came in the aftermath. Multinational companies with multinational and, consequently, complex supply chains experienced the most problems. Small ripples and disruptions at the upstream end of supply chains were amplified as supply chains moved downstream. The situation was better for local suppliers, as raw materials or components came from closer to the country of destination, and they were better able to anticipate fluctuations in demand and availability. The procurement manager of Company A described the availability situation during COVID-19 as follows:

"Availability problems were concentrated on a small number of products and not even regularly on any of them."

This was because many suppliers still had many products in stock, and the situation in China took time to affect availability. In addition, the product categories affected by availability

problems varied widely. However, according to the procurement manager of Company A, microprocessors, sensors, and microcontrollers experienced the worst shortages during the pandemic. However, according to Company A's procurement director, the impact of the COVID-19 pandemic on availability was not felt until well after the first wave of the pandemic.

The war in Ukraine also had a massive impact on the availability of raw materials and products at a global level. In particular, large companies operating globally experienced severe disruption, according to Company A's procurement director, as they are linked to large supply chains and as a result, the problems are exacerbated. In addition, an industrial cable manufacturer's factory in Germany had been hit by a mudslide during the Flood Catastrophe. It was out of action for an extended period, having to be completely rebuilt. As a result, components from this manufacturer were not available at all, causing severe availability problems. There are, therefore, many types of disruption, and they also have very different effects on availability. All the disruptions mentioned above caused very large-scale problems in the supply chains, particularly in the availability of components and products. In the electrical supplies sector, according to the procurement director of Company A:

"This was very strongly felt in the aftermath of the war in Ukraine, where there were huge problems in the supply of steel, aluminium and copper, which come mainly from Russia."

Customers wanted a component from a particular manufacturer because it was best suited to a particular piece of equipment, which also caused demand problems. However, the situation calmed down relatively quickly, as customers realised there was nowhere to get the product. The purchasing manager of Company A added that, in addition to the availability problems, the war caused strong inflation of raw material prices, which also affected the overall purchase price. In addition, the war also had a knock-on effect on the logistics of deliveries from the Far East. For a long time, suppliers' subcontractors delivered products and components via the trans-Siberian railway, which used to be a more cost-effective and faster way of transporting goods from the Far East to Europe. This situation changed, however, as imports from Russia were no longer allowed due to sanctions, which eventually affected prices.

The situation has been similar for the suppliers of company A. Company B (supplier) mainly buys raw materials, in particular steel. This market has been undersupplied, meaning steel prices have risen significantly in recent years. In 2021-2022, prices increased by 30-40% in one quarter. The representative of Company B also mentioned that the impact of the COVID-19 pandemic was not as severe as the consequences for supply chains during the war in Ukraine. This was mainly due to the availability problems in February and March 2022 due to the war after the Russian steel imports had stopped. Prices, therefore, fluctuated regularly, causing pricing problems. This had a significant impact on pricing, purchases and thus on the business of company B. However, the security of supply has improved slightly since 2023. However, supply disruptions still persist (Purchasing Manager, Company B).

According to Company B, concrete examples of supply chain disruptions include the end of steel supply in spring 2022. Plates and coils were no longer available as regularly as before. Deliveries were not made every week but every month, so stock management was eventually very challenging, and everyone ordered more raw materials, leading to further problems. This situation led to the Forrester phenomenon or bullwhip effect. This phenomenon refers to a situation where there is an increase in the variability of orders, restocking and stock levels as a supplier moves from supplier to production. The upstream supplier tries to limit order volumes by supplying only a certain percentage of the order placed, and this leads to the downstream consumer starting to misinform the upstream supplier and placing a larger than required order to meet product needs. (Kowalczyk, 2017) This phenomenon can lead to several disadvantages, such as overproduction in the supply chain, inventory, transportation, backorders and poor service levels. Service levels can also be poor, resulting in lost sales and the need to re-supply. Production planning becomes more complex, and capacity decisions may need to be corrected. These factors, in turn, lead to lost sales. Many of these also happened to the target companies. Company B's problems can, therefore, be summarised as an increase in the price of raw materials, an increase in the value of stocks, higher quantities being ordered, margins suffered, and prices had to guarantee the ability of production to meet customer demand. So, as a rule, products were bought, but they arrived late and cost considerably more than before.

The representative of company C (supplier) also stressed the importance of identifying and reducing disruptions in supply chains. He put it as follows:

“With the COVID crisis everywhere in the supply chain has been identified, that there is quite a lot of risk which can suddenly influence the supply chain.”

Before that crisis, the main idea of every company was profitable growth, based mainly on low-cost sourcing and making profits from manufacturing and low-cost countries. However, this crisis changed the thinking somewhat. Factories were located in Asia during the COVID-19 pandemic, so products were unavailable internationally. Another risk, according to Logistics Director C, was the Suez Canal obstruction. A ship got stuck in the Suez Canal in March 2021, blocking the waterway for six days (Lee & Wong, 2021). Company C's representative added: *"That's where we learned that we must start acting."* The war in Ukraine also affected the company's operations precisely because of the raw material stocks held by suppliers. The prices of components and products also increased in company C. The war has particularly disrupted the production of printed circuit boards or processors. Demand was, therefore, very high and supply very low. Representative C also stated that the COVID-19 pandemic was worse for the company than the consequences of the Russo-Ukrainian war precisely because of the international supply chains. Risk management has become the core of Company C since these disruptions. It has, therefore, been the subject of much reflection and study, and strategies have been developed to mitigate it.

Table 6: Problems Caused by Disruptions in Electrical Equipment Supply Chains

Causes of supply chain disruptions:	Problems caused by disruptions:
The COVID-19 pandemic (2019-)	Supply Chain Blockage (Flood Catastrophe/ Suez Canal obstruction)
The Russo-Ukrainian war (2022-)	Logistical Disruptions and Shipping/Logistics Delays (Suez Canal obstruction)
Flood Catastrophe in Europe (2021)	Component Gaps/ Extended and Unreliable Delivery Times: Shortages of components such as circuit boards, microprocessors, sensors and microcontrollers (All crises)
Suez Canal obstruction (2021)	Impact on Steel, Aluminium, and Copper Supply (The Russo-Ukrainian war)
	Product Price Increases (The Russo-Ukrainian war)
	Stagnation of international supply chains/ Delivery Failures (COVID-19 pandemic)

4.1 Risk Assessment in Target Companies

The aim of this section is to identify which disruptions and availability problems have the greatest impact on companies' supply chains and thus on their business. This will provide a comprehensive picture of which areas of risk management need to be addressed and which mitigation strategies need to be put in place. As already mentioned in the theory section. Risk assessment is done using a matrix to determine the probability and impact of an event, with 1 being the lowest probability and impact, while 5 being the highest probability and impact. The higher the probability and impact, the more severe the outcome of the event and the higher the score (Richert & Dudek, 2023).

The risk assessment template given to Target Companies A, B and C contained a number of risks that they had to assess. The risks were measured on the basis of an average, i.e., all the data in the risk assessment matrix were averaged together to produce the mean value on

which the data were based. The assessment showed that the lowest scores were Transport and logistics delays (3), Problems with supplier reliability (4), and Natural disasters (4). These risks therefore have only a low or low moderate level. In other words, the risks have a very small impact on the company's business, although their probability is sometimes at the medium level. However, their risk management is less critical as we move towards medium and low severity levels. Mitigation strategies are in place for these risks, but they are calculated on a day-to-day basis and are therefore managed at an operational level on an ongoing basis. Only the Natural disasters level also needs to be addressed with long term mitigation models. This is discussed in more detail in the next section on mitigation strategies.

Risks such as Availability risks (6), Stock shortages (6), Fluctuations in transport costs (6), Technological disruptions (6) and Policy or regulatory changes affecting imports/exports (6) are at the upper moderate level. It is therefore important to address these, which have a very high probability and an impact of around level 2-3. However, a large proportion of these disruptions are part of preventive risk management measures and are based on continuous monitoring by procurement experts and are therefore addressed on an ongoing basis within companies, as reported by a representative of Company A.

According to the risk assessment study, the main risk impacts are Financial stability of the supplier (8), Quality control problems leading to production delays (9), Labour disputes affecting the supplier's or manufacturer's workforce (9) and Global economic conditions affecting the supply chain (12). In particular, global economic conditions have a particularly large impact on business. However, it can be said that all the above risks are still high-level risks and not extreme risks for which immediate preventive action must be taken. However, because of the high impact, these are situations and risks for which it is important to have some form of mitigation strategies in place, as the impact on supply chains and the business as a whole is very serious if they occur. These strategies are discussed in later sections. In Table 7, these risks are further summarised in a risk assessment matrix.

Table 7: Risks Based on Probability and Impact

Likelihood:	Consequence Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost certain 5					
Likely 4					
Possible 3	C (3)	A (6) D (6) L (6)	I (9) J (9)	K (12)	
Unlikely 2		B (4)	F (6) G (6)	H (8)	
Rare 1				E (4)	

A = Availability risks	E = Natural disasters	I = Quality control problems leading to production delays
B = Problems with supplier reliability	F = Technological disruptions	J = Labor disputes affecting the supplier's or manufacturer's workforce
C = Transport and logistics delays	G = Policy or regulatory changes affecting imports/exports	K = Global economic conditions affecting the supply chain
D = Stock shortages	H = Financial stability of the supplier	L = Fluctuations in transport costs

4.2 Solutions to Supply Chain Disruptions in Recent Years

In recent years, disruption risks and strongly linked availability problems occurred in all target companies during the same crises in 2020-2023. In target company A, the COVID-19 pandemic and the war in Ukraine have caused difficulties in supply chains. The company had to react relatively quickly during these periods. As mentioned in the theory section, the first thing to do is to identify the risks and determine the origin of the risk. (Kern et al., 2012) The procurement manager of Company A mentioned that after the outbreak of the COVID-19 pandemic, the analysis of the countries of origin of all products started, especially the products coming from China, which was very critical as it is a massive supplier of electronic components. Hence, they had to be addressed quickly. The company's procurement manager also indicated that it was essential to identify which products might be affected by the pandemic in general, the primary hypothesis being that the availability of electronic components made in China or elsewhere might be affected if supply chains were interrupted. A risk assessment follows this, the second step of the supply risk management conceptual model. (Kern et al., 2012). As a result, inventory levels were also increased significantly to maintain demand and supply customers. BayPower (2022) also refers to the situation. Keeping an electrical component buffer can keep the supply chain running during disruptions. The buffer is, therefore, a good anticipatory tool in case of future disruptions. However, too much stock is not good so it needs to be sized carefully. Maintaining the quality of components is important, as cheap components cause problems in supply chains, especially in availability and create downtime. In the worst case, this can lead to the loss of the customer. Therefore, investing in quality components is important, even if the cost is slightly higher. This is because a simultaneous supply chain disruption and high demand only exacerbate the problem; for example, in the best-case scenario in the electrical goods sector, green shift products are in high demand. Company A's procurement manager summarised the lessons learned from the pandemic as follows:

"What we have learned is that the initial response needs to be quick and stakeholders need to be informed of any future shortages. Getting reliable information is a challenge."

The same situation of identifying the target country was also discussed at the outbreak of the war in Ukraine in Company A. This situation was used to identify which products were arriving from Russia, Ukraine and Belarus, as these were the countries most affected by the

problems. The COVID-19 pandemic has, therefore, already taught us that identifying the country of origin is critical for supply chain risk management. In addition to these issues, many additional complementary suppliers were sought from elsewhere, in addition to the main suppliers, to avoid disrupting supply chains and blocking the entry of goods. According to the purchasing manager of Company A, this complementary supplier strategy was already in use before the crises but became even more critical during them. Unexpected risk events also changed customer demand: before the crises, customers wanted only one particular supplier's product, while the pandemic and the war meant that similar products from other manufacturers became acceptable. Another solution to the problem of mudslides was substituting the same type of product from a different manufacturer. This strategy did not then interrupt sales. Company A's purchasing manager mentioned that it is always possible to plan for disruptions sometime in the future. However, planning for a disruption of availability beyond two months is very challenging. However, suppose supply chain disruptions become as bad as in the last few years and last for several months. In that case, it is almost impossible to plan appropriately for them, as problems have already arisen with the availability of raw materials that are blocking the supply chain.

Company B mentioned that just-in-time strategies became just-in-case strategies, forcing the company to think differently and develop more extensive raw materials and product stocks. Goods did not arrive when needed, leading all companies to build up more extensive stocks to ensure production and sales. However, this strategy caught on with more companies and caused further availability problems due to a shortage of raw materials. This led to a new price increase. However, such situations had to be lived with as they affected all steel companies worldwide.

The sourcing strategy has been a solid multi-supplier strategy over the last year due to the desire to minimise the risk of that one key supplier not being able to supply the desired number of components. In addition, new backup suppliers are constantly being sought and identified to ensure that the supplier base is as broad as possible. For Company B, the purchasing strategy is mainly focused on maintaining high stocks, particularly of raw

materials and products, to meet demand and ensure that production is always able to manufacture products to meet customer demand.

According to the representative of Company C, market forecasting is a vital part of risk management. This is also why, as already shown by companies A and B, communication with the different stakeholders has been crucial in times of crisis, be it the COVID-19 pandemic, the Russo-Ukrainian war, the situation in Suez or natural phenomena such as mudslides or fires. Communication with the various stakeholders is essential in any disruption. Moving goods between warehouses also solves many disruption problems; if one company has excess stock in one warehouse, it can be balanced. To this end, the planning team at Company C carries out a monthly review of stocks and requirements in different parts of the world. This helps prevent disruption in the short term.

A good example of this is the COVID-19 period when supply chains were completely paralysed; another similar example is the Suez disruption. Investing in the upstream end of the supply chain is, therefore, also very crucial. Company C's stocks consist mainly of production stock and, in particular, of electronic components because, in the last three years, there was a lack of availability of electronics on the market, which has caused tensions, and this mitigation model has worked well for this problem. Those decisions in situations like this always come from senior management. The strategy of bringing some suppliers or production facilities closer to the company has also been very present in Company C. This strategy works to prevent extended supply chain disruptions. Company C's representative summed it up as follows:

“Geographical concentration is therefore, at least from my point of view, a thing of the past. "

Costs are also rising in China, making it a good idea to move suppliers and plants to other countries. R&D technology and development, including artificial intelligence, are also vital to future flexibility in terms of supply, according to the representative of company C. These strategies have thus helped with various disruptions in the last years.

4.3 Effective Risk Management Mitigation Strategies to Prevent Disruption and Availability Risks

Depending on their severity and regularity, there are very different risk management tools for disruption risks and related availability problems. Therefore, mitigation strategies can be divided into regular short-term (operational) and long-term (strategic) mitigation strategies. This work examines the situation of a B2B electrical wholesaler and the supply chain situation of this company. In this context, the company in question can also be referred to as an availability business. Such a company has the idea of guaranteeing availability to customers as much as possible. According to the representative of Company A, the anticipation and risk management of availability-related disruptions were already very important before the disruptions mentioned above. However, it was even more critical during the crises. However, another company representative indicated that there is no single correct strategy for preventing disruption risks; it consists of several different factors. The response to situations is, therefore, case-by-case. However, in the short term, monitoring and controlling the supply chain's ability to deliver is essential. Monthly, suppliers are discussed and informed about their performance. According to Dfreight (2023), cooperation with suppliers is generally important to ensure the best possible supply chain performance. In addition, SLAs are in place to ensure that suppliers are also performing according to the rules. An SLA (Service Level Agreement) is a service contract between a customer and a service provider that defines a certain level of service requirements. To this extent, preparing for availability risks is a daily activity. This is done by controlling and monitoring the daily purchase in a system-driven way, automatically generating lists of unconfirmed and overdue items, which are used to send a message to the supplier and find out where the products are delayed. A possible explanation for the delay or a new possible date is then obtained. Therefore, the long-term performance history is regularly checked to be prepared in case the supplier in question delivers late or less frequently. Purchasing forecasts are also discussed with suppliers. The aim of sharing purchase forecasts with suppliers is, therefore, to get the supplier to prepare for future orders and, thus, to strengthen availability. Information systems, therefore, support day-to-day operations, but they also help to anticipate. The algorithms in these systems, therefore, calculate the likely demand for components. Inventory control is parameterised based on the supplier's track record. Supplier audits are also a common way of looking at supplier reliability. In addition, business partner

assessment is also an essential part of this supplier review. There will be direct customer file information if there are any disruptions in financial matters and payment behaviour. There are many ways to be prepared, i.e. the more significant the partner, the more scrutiny and monitoring of that supplier. This is done to address availability risks and all other risks, such as political and financial risks.

In the longer term, disruptive events on a global scale are generally dealt with separately and require daily discussion with suppliers. According to the procurement manager of Company A, in such situations, more than monthly meetings are required as the reaction time affecting availability would be too short. Procurement Manager A indicated that risk mapping is generally carried out daily in Company A, with a slightly lower frequency for significant risks because the probability of these risks is relatively low. However, risk mapping is carried out continuously if a crisis is in progress. Report to suppliers on how their activities look from the client's point of view. Transparency is therefore reflected in the fact that they have the same information as the buying company. A vital mitigation strategy in the long term, according to the company's procurement manager, is to monitor the global market situation, especially for raw materials, in order to see in advance which products will be subject to shortages and to be able to forecast shortages of specific components. Inventory management is one of the most important ways of dealing with availability and disruption risks. The idea is to keep many substitute products in stock at all times, which can replace another product in an emergency. Company A's representative also mentioned that the current trend is to shift production back to the buffer zone. However, it was the opposite before the disruptions of the last few years. Company A's procurement manager summed it up as follows:

"Nowadays, there is also more risk management and not just a cost-effectiveness perspective."

In addition to the strategies mentioned above, the strategies of the leading suppliers and complementary suppliers mentioned earlier are essential for risk prevention in the long term. BayPower (2022) also mentions this strategy in its text. Back-up suppliers are constantly sought to ensure the availability of the main supplier in case of disruption. The agreements

with the main suppliers also already provide that if the company is the primary customer and therefore, in the event of a disruption, the products go first to the target company, this strategy will also reduce the risk of a disruption in availability. The representative of company A mentioned that the company has several logistical hubs all over Europe. Finland has a large number of suppliers, but there are also many warehouses in Sweden. In addition, products also come from Central Europe, such as Germany, the Netherlands and France. So there are several suppliers across Europe, which makes it easier to deal with any disruptions.

Supplier B updates its organisation-wide risk management strategy once a year for disruption events. Potential risks are identified across the business, not only for procurement but also for production, but in the coming years, more attention has been paid to risks related to procurement, especially availability. According to the procurement manager of Company B, this is due, in particular, to the consequences of the war in Ukraine, which has significantly impacted the availability of raw materials. In this update, potential risks have been categorised according to their likelihood and impact. This provides a comprehensive picture of the potential risks. In addition to these risk mapping exercises, a supplier risk assessment is carried out twice a year; the daily work also provides a lot of information on the risk situation in the market as the expert team has a sufficiently good view of the market. Meetings are held with suppliers on an ongoing basis to be aware of possible disruptions and availability problems so that they can be quickly addressed. In addition, suppliers are expected to act responsibly, so there is no transparency tool for this. Company B's suppliers also manage risk within their own company to ensure transparency in the supply chain and minimise risks. This tool, therefore, provides a good understanding of the supply chain situation in risk discussions and helps to anticipate risks.

Company C's management team determines risks globally. The representative of Company C stated that the management team determines risk through the Hoshin model. The Hoshin Kanri, also known as policy deployment, ensures that a company's strategic objectives drive progress and action at all levels. This model explains how risk is addressed and how the company deals with it from the management team down to each unit. The unit level takes this part of the guidelines and then expands and reduces it for its operations. In addition to this model, Company C has a massive document describing all the company's risks, which

is stored in the Business Continuity Plan (BCP). The risk has, therefore, been identified, and efforts have been made to find the root cause. It has also tried to find some kind of solution and mitigation plan for the potential risk. If a solution to the risk has been found, it is confirmed. This document is based on the experience of recent years and has been expanded to include new risks as they arise. This document, therefore, provides a comprehensive basis for determining the company's formal risk management approach when a risk arises. A solution has also been found for situations where the system is inaccessible, for example, during a power failure. Company C's representative describes the situation as follows: 'There are up to three distribution centres in Europe that can take over and deliver to this region when there are technical problems, which means that we route the order to Hungary or France, for example, and they deliver directly to this region without travelling.' Company C has, therefore, gone a long way in identifying, assessing and mitigating risks through AI and sound engineering systems, with some form of prevention strategy in place for each risk in the company's BCP. So, it is vital to have a company-wide practice to implement policies and address potential risks similarly across the board. So, introducing policies and the BCP is a comprehensive way of identifying and investigating risks. It also provides the whole company with possible prevention models. In addition, the strategy of alternative sources of supply is an excellent way of avoiding disruption in a particular area.

It can, therefore, be said that mitigation strategies are very varied and can be summarised as good supplier and customer cooperation, operational daily availability control, i.e., systematic monitoring and rapid action, supply chain analysis to identify the countries of origin of components and raw materials, analysis, detection and screening of the supplier pool, combined with regular meetings and contracts, main and complementary supplier strategy, inventory management and related wide product range, switching suppliers closer to the target country. In addition, information systems are a key tool for ensuring disruption and availability and are used daily in the mapping process.

Table 8: Risk Mitigation in Electrical Equipment Supply Chains

Mitigation methods:	
Operational Actions and Immediate Response Protocols: Systematic monitoring mechanisms for day-to-day operational control and response protocols. Including Planning purchases in advance, Maintaining a component buffer and quality, Regular tracking of deliveries	**Inventory Management Practices:** Emphasizing optimal stock levels to serve as a buffer against disruptions and ensure continuous operational flow
Diversified Product Portfolio Management: Strategic diversification of the product range and mitigation of the impact of potential disruptions	**Contracts and Regular Stakeholder Meetings:** Ensure contract accuracy through detailed agreements and frequent stakeholder meetings
Strategic Diversification with Main and Ancillary Suppliers: A strategy combining primary and secondary suppliers to increase diversification and reduce dependence on single sources	**Supply Chain Analysis:** Undertake a comprehensive scrutiny of the supply chain architecture, meticulously identifying the geographic origins of critical components and raw materials
Supplier Pool Analysis: Diversifying the supplier base. Multiple suppliers for one component	**Strategic Collaboration with Suppliers and Customers:** Robust inter-organizational relationships to create collaborative frameworks that strengthen the supply chain in the event of disruption
Leveraging Information Systems for Real-Time Oversight: Using information systems as key tools for supply chain mapping, ensuring supply chain transparency, technological developments (data analysis tools and AI)	**Continuous Monitoring for Disruption and Availability:** Information systems in place for continuous monitoring, tracking disruptions and availability, enabling proactive responses and strengthening supply chain resilience
	Geographic Proximity in Supplier Selection: Deliberately choose suppliers that are geographically close to the target country to minimise logistical problems and reduce the risks associated with long supply chains.
	In-House Manufacturing in Large Companies: Enables better control of production processes, reduced dependence on external suppliers and the ability to adapt quickly to supply chain disruptions

5 Discussion

The section examines the main research question, *"How to manage supply chain disruptions in the B2B electrical equipment sector supply chains?"* The risk management framework can be a good tool for this, as it is the basis for managing disruptions. Kern et al. (2012) delineated risk management into three core components: identification, assessment, and mitigation, with the possibility of incorporating monitoring into this framework. This discussion aims to delve more deeply into the interview findings, scrutinizing them and drawing comparisons with established theories. Leveraging the triad of identification, assessment, and mitigation, we will elucidate the identified risks, delve into the assessment methodologies employed, and expound on the mitigation strategies applied to tackle these risks.

The initial phase involves the meticulous identification of risks, as highlighted in the theoretical framework. The study focuses on disruption risks and the ensuing implications for availability. Kleindorfer and Saad (2005) categorize disruption risks into three groups: operational uncertainties, natural disasters, and man-made threats. Notably, recent years have witnessed a significant prevalence of natural disasters and man-made threats, causing substantial disruptions in the supply chains of the electricity utility industry. Interview insights reveal that significant disruptions in the past four years, including the COVID-19 pandemic, the Russia-Ukraine war, the Suez Canal blockage, and the Central European floods, have profoundly impacted supply chains. These disruptions have also been shown to affect product availability. In literature such as Ivanov (2020), El-Baz & Ruel (2021), NASDAQ OMX (2021), and Knox (2023) texts have echoed the impact of crises on supply chains. Notably, the Russo-Ukrainian war (2022-) has specifically affected the availability of crucial raw materials like steel, copper, and aluminium due to supply disruptions and prolonged delivery times, contributing to heightened prices and delayed availability; representatives across all companies consistently report these findings.

Knox (2023), in the literature, also underscores these raw material challenges and resultant price increases. Furthermore, the identified disruptions have led to logistical delays for components from the Far East, while products transiting through Russia faced challenges due to sanctions. The COVID-19 pandemic added to the complexity of disruptions in international supply chains, leading to shortages of specific components as supplier stocks depleted. Similar disruptions were observed in the aftermath of the Ukraine conflict, where product categorization proved intricate.

The German mudslide (2021) resulting from floods resulted in the closure of an entire factory, rendering the entire product line entirely unavailable. In summary, availability risks encompass supply chain disruption, logistical challenges, and subsequent component shortages. The Suez Canal obstruction (2021) further exemplified serious issues for suppliers, including supply chain blockages, component shortages, and logistical complexities. In essence, recent disruptions have been well-identified, yielding myriad consequences on product availability in the long run. Fortunately, proactive measures are often taken in advance, as elaborated in the subsequent sections.

The second stage of the risk management process involves risk assessment. As highlighted by Kern et al. (2012), the primary objective of risk assessment is to deepen the understanding of identified risks. Richert and Dudek (2023) advocate for this through risk mapping, a method evident in the operations of the target companies. The overarching goal is to minimize the likelihood of risks and comprehensively avoid or mitigate their impacts. Acknowledging that risk is an inherent possibility, a robust understanding of the probability of risk is essential (Kern et al., 2012). Kleindorfer and Saad (2005) emphasize the importance of identifying critical risks with the most significant impact on a firm's operations.

Hendricks and Singhal (2003) contribute by asserting that the speed of risk development and the duration of the risk event influence disruptions. Consequently, it is crucial to prioritize identified risks accordingly. In the context of the target companies, disruption risk assessment involves identifying the countries of origin for products to assess the potential impact on product categories and availability in the target country. Digital tools (A, C) and

risk mapping within the target company (B) were employed for this purpose. In this thesis, disruption and availability risks were mapped based on probability and severity. The study revealed that major disruptions, such as natural and man-made threats to supply chains, have a high impact (4) but relatively low probability (1), which means a total score of 4 compared to more frequent disruptions like availability problems, transport and logistics delays (3), stock shortages (6), and fluctuating transport costs (6), which have a higher medium probability but a relatively lower impact. It also emphasized the need for a case-by-case approach in dealing with major disruptions, as each event has specific characteristics. For instance, the Suez crisis impacted availability differently than the Russo-Ukraine war, which was primarily a logistical issue rather than a complete supply chain standstill due to the closure of production plants, as noted by representatives of company A.

Furthermore, the study identified global economic conditions affecting the supply chain as having the most significant impact (4) and likelihood (3) of occurrence, with a total score of 12. Over recent years, the frequency and severity of such economic conditions have prompted companies to be particularly vigilant in response to these challenges.

In addition to the first main research question, one sub-question was addressed: *"What kind of risk management mitigation tools can address disruption and availability risks in B2B electrical equipment supply chains?"* There were many different models for this, both in the literature and the empirical part. Risk mitigation can be categorized into two phases: short-term and long-term strategies. Target companies employed diverse approaches to tackle disruption risks and associated availability issues. The summarized mitigation strategies include diversified inventory management with ample backup stocks and a broad array of high-quality products echoed by all three target companies. This approach, extensively discussed by Inman and Bhaskara (2019), is a fundamental pillar in mitigating disruption risks.

Critical to risk management is IT monitoring, involving routine operational activities like reviewing order lists for overdue and unconfirmed purchase lines and monitoring and querying overdue purchase lines. This aspect is underscored by representatives from

companies A and C, aligning with the emphasis placed by Olson (2014) and Inman and Bhaskaran (2019). Information systems and supply chain transparency improvements play a crucial role in mitigation. Collaboration with suppliers for transparency, highlighted by companies A, B, and C and in works by Tang and Musa (2011) and Olson (2014), emerges as a versatile risk mitigation tool. Cooperation agreements, noted by Company A's representative, are deemed crucial for a competitive edge, echoing insights from Olson (2014) and Inman and Bhaskaran (2019).

Additionally, diversification of the supplier base and maintaining a multi-supplier strategy are emphasized by target company representatives and Olson (2014). Having a primary supplier, multiple backup suppliers, and a broad product range aids in rapid risk management, aligning with Olson's suggestions. Senior management support in risk management, highlighted by Company C's representative and Berg, Knudsen, and Norrman (2008), is pivotal. An enterprise-wide Business Continuity Plan (BCP) and a comprehensive policy deployment are essential. Large companies exploring self-provisioning and relocating suppliers closer to the target country, suggested by Inman and Bhaskara (2019), are considered viable solutions in current trends. All the strategies above are derived from company interviews and are prevalent in general risk management literature. Table 9 encapsulates identified risks, assessments, and mitigation strategies for clarity.

Table 9: Summary of Disruption and Related Availability Problems in Electrical Equipment Supply Chains

Origins of Supply Chain Disruptions and Specific Challenges Related to Availability disruption:		**Mitigation strategies:**
The COVID-19 pandemic (2019-)	Stagnation of international supply chains, Shortages of components, Extended and Unreliable Delivery Times, Time Delays, Delivery Failures	**Main solutions:** (1) Continuous Monitoring for Disruption and Availability, (2) Geographic Proximity in Supplier Selection, (3) Supplier Pool Analysis, (4) Strategic Collaboration with Suppliers and Customers, (5) Inventory Management Practices **Other:** (6) Contracts and Regular Stakeholder Meetings, (7) Leveraging Information Systems for Real-time Oversight, Ensuring supply chain transparency, technological developments (data analysis tools and AI)
The Russo-Ukrainian war (2022-)	Impact on Steel, Aluminium, and Copper Supply, Extended and Unreliable Delivery Times, Component Gaps/Shortages of components, Product Price Increases	**Main solutions:** (1) Inventory Management Practices, (2) Diversified Product Portfolio Management: Maintaining a component buffer and quality, (3) Planning purchases in advance, (4) Contracts and regular stakeholder meetings **Other:** (5) Supplier Pool Analysis, Diversifying the supplier base. Multiple suppliers for one component
Flood Catastrophe in Europe (2021)	Supply Chain Blockage, Component Gaps/Shortages of Components	**Main solutions:** (1) Inventory Management Practices, (2) Strategic Diversification with Main and Ancillary Suppliers. **Other:** (3) Supplier Pool Analysis, Diversifying the supplier base. (4) Multiple suppliers for one component, (5) Continuous Monitoring for Disruption and Availability
Suez Canal obstruction (2021)	Supply Chain Blockage, Shortages of components, Time Delays, Logistical Disruptions and Shipping/Logistics Delays	**Main solutions:** (1) Diversified Product Portfolio Management: Maintaining a component buffer and quality, (2) Strategic Diversification with Main and Ancillary Suppliers, (3) Supplier Pool Analysis, Diversifying the supplier base. Multiple suppliers for one component **Other:** (4) In-house manufacturing in large companies

6. Conclusions

In recent years, global companies have paid increasing attention to disruption risks because of their profound impact. Nearly every company has struggled with challenges arising from disruptions like the COVID-19 pandemic, the Ukraine conflict, the Suez Canal blockage, and natural disasters such as floods in Central Europe, all significantly impacting global supply chains. Identifying and managing these risks has become paramount and will continue to be crucial.

The discussed Master's thesis delves into this urgent issue within the context of electrical equipment supply chains. Employing diverse methodologies, the study identifies disruptive factors and elucidates the risks and repercussions of their occurrence. The COVID-19 pandemic presented substantial challenges to electrical supply chains, resulting in international standstills and component shortages. Similarly, conflicts in Russia and Ukraine disrupted the availability of essential metals, particularly affecting circuit boards, microprocessors, sensors, and microcontrollers. Major natural disasters, like floods, worsened availability issues by causing supply chain blockages and facility destruction, leading to component shortages. The Suez Canal blockage also contributed to supply chain disruptions and logistical challenges.

It is crucial to note that there is no one-size-fits-all approach to dealing with disruptive risks, given the unique circumstances of each situation and supply chain. The geographical location of a company also influences the severity of disruptions and their consequences. Mitigation strategies in the electrical supply sector closely align with those in other commodity businesses. Inventory management, including increased stock levels, is considered crucial, and robust risk mapping, coupled with continuous monitoring, is an essential aspect of risk management in this sector. Investments in information systems, contracts, and effective communication with suppliers and stakeholders aim to enhance preparedness. Additionally, strategic decisions involving key and ancillary suppliers and

diversification of the product range significantly contribute to risk mitigation. The relevance of geographical proximity has gained prominence as a means of reducing supplier risks.

Integrating vital information systems for real-time and continuous monitoring enables proactive responses. A notable challenge arises when specific customers require precise components tailored to specific equipment from particular manufacturers. Solutions are being developed to mitigate customer dependence on single components and enhance the overall efficiency of supply chains. In essence, managing supply chain risks is a complex undertaking. Various risk management methods and strategies exist, and no universal solution or effective strategy exists for all availability risks. The strategy for mitigating and anticipating risks is highly company-specific, influenced by factors such as supply chain situation, length, components, geographical location, and numerous other variables.

5.1 Discoveries and Observations

All targeted companies experienced similar disruptions, prompting comparable solutions and mitigation strategies to be adopted. This indicates the broad effectiveness of the mentioned mitigation models. However, it is essential to emphasize that there is no one-size-fits-all solution; instead, diverse strategies may be required. The choice of an appropriate mitigation strategy hinges entirely on the specific problem that triggered and contributed to the disturbance. It is crucial to highlight that the utilities sector's response to the consequences of the COVID-19 pandemic differed significantly from its reaction to the impacts of the war in Ukraine. This underscores the distinctiveness of each situation, necessitating a tailored approach based on the unique factors contributing to the disruption.

5.2 Future Follow-up Topics

Exploring this subject in the future holds considerable promise despite the limited research on procurement, particularly in risk management. There is a clear call for more comprehensive investigations. This section delves into potential future topics for exploration, with one promising direction involving a shift from qualitative to quantitative research. Specifically, attention could be focused on risk assessment and its associated mapping.

Another thematic area for exploration involves examining the same topic within a different company or industry. Such an approach has the potential to reshape research focus, especially considering the significant changes in supply chains and raw materials. The services sector, in particular, presents an intriguing angle for investigating risk management, as disruptions in supply chains may have distinct consequences across various sectors. Alternatively, a meticulous scrutiny of a single disruption, such as the impact of the COVID-19 pandemic or the Russo-Ukrainian war on supply chains, could provide a more precise and detailed analysis. Different risks could also be studied in different sectors. In addition, different risk management models could be studied in different business areas.

Moreover, integrating these suggested follow-up topics can generate novel research directions. Given the contemporary importance of risk management in supply chains, there is an imperative for procurement to delve into more intricate studies. The evolving landscape implies that new disruptions and potential challenges may emerge at any given time, underscoring the need for a deeper understanding of risk management within procurement.

6 References

Arabshahi, H. & Hamed, F. (2019) 'Risk analysis for innovative activities in production systems using product opportunity gap concept', The TQM Journal, 31, pp. 1028–48.

Bay Power - Electrical solutions. (2022) 'Current Global State of Electrical Components Supply Chain', [Online] Available at: https://www.baypower.com/blog/current-global-state-of-electrical-components-supply-chain/ (Accessed: 10.10.2023).

Berg, E., Knudsen, D. and Norrman, A. (2008) 'Assessing performance of supply chain risk management programmes: a tentative approach', *International Journal of Risk Assessment and Management*, 9(3), pp. 288-310.

Brandon-Jones, E., B. Squire, and Y. G. T. Van Rossenberg. (2015) 'The Impact of Supply Base Complexity on Disruptions and Performance: The Moderating Effects of Slack and Visibility', *International Journal of Production Research*, 53(22), pp. 6903–6918.

Christopher, M., & Peck, H. (2004) 'Building the resilient supply chain', *The International Journal of Logistics Management*, 15(2), pp. 1-14.

Christopher, M., Mena, C., Khan, O., Yurt, O. (2011) 'Approaches to managing global sourcing risk', Supply Chain Management: *An International Journal*, 16(2), pp. 67–81.

Chopra, S., Reinhardt, G. and Mohan, U. (2007) 'The importance of decoupling recurrent and disruption risks in a supply chain', Naval Research Logistics, 54(5), pp. 544-55.

Chopra, S., Sodhi, M.S., (2004). Managing risk to avoid supply-chainbreakdown. MIT Sloan Management Review 46 (1), 53–62

Chopra, S., Meindl, P. (2015) 'Supply chain management: strategy, planning and operation', 5th edn. Pearson, Harlow.

Ciotti, M. Ciccozzi, M. Terrinoni, A. Jiang, W. Wang, W. Bernardini, S. (2020). The COVID-19 pandemic. Volume 57, 2020 - Issue 6: Special issue: COVID-19 Pandemic and the Critical Role of the Clinical Laboratory. Pages 365-388

Co, H. C., I. David, P. Feng, and E. Patuwo. (2012) 'A Continuous-Review Model for Dual Intercontinental and Domestic Outsourcing', *International Journal of Production Research*, 50(19), pp. 5460–5473.

Cui, L., Yue, S., Nghiem, X., Duan, M. (2023) 'Exploring the risk and economic vulnerability of global energy supply chain interruption in the context of Russo-Ukrainian war', Resources Policy, 81.

Deiva Ganesh, A., Kalpana, P. (2022) 'Supply chain risk identification: a real-time data-mining approach', *Industrial Management + Data Systems*, 122(5), pp. 1333-1354.

Demeter, K. (2014) 'Operating Internationally – The Impact on Operational Performance Improvement', *International Journal of Production Economics*, 149, pp. 172–182.

Dfreight. (2023) 'An Insight into Schneider Electric supply chain strategy', [Online] Available at: https://dfreight.org/blog/schneider-electric-supply-chain-strategy/ (Accessed: 15.,10.2023).

Dupont, L., C. Bernard, F. Hamdi, and F. Masmoudi. (2018) 'Supplier Selection Under Risk of Delivery Failure: A Decision-Support Model Considering Managers' Risk Sensitivity', *International Journal of Production Research*, 56(3), pp. 1054–1069.

El Baz a, J., Ruel, S. (2021) 'Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era', *International Journal of Production Economics*, 233.

Ganesh, D A., and P. Kalpana, P, (2022). "Supply Chain Risk Identification: A Real-Time Data-Mining Approach." *Industrial management + data systems* 122.5 (2022): 1333–1354

Gaudenzi, B., Borghesi, A. (2006) 'Managing risks in the supply chain using the AHP method', *International Journal of Logistics Management*, 17(1), pp. 114–136.

Gurnani, H., Mehrotra, A., Ray, S. (2012) 'Supply Chain Disruptions: Theory and Practice of Managing Risk', Springer-Verlag, London.

Gurtu, Amulya, and Jestin Johny. "Supply Chain Risk Management: Literature Review." *Risks* 9.1 (2021): 1–16. Web.

Hallikas, J., Virolainen, V.M. and Tuominen, M. (2002) 'Risk analysis and assessment in network environments: a dyadic case study', *International Journal of Production Economics*, 78(1), pp. 45-55.

Hallikas & Lintukangas (2016) 'Purchasing and supply: An investigation of risk management performance', *International Journal of Production Economics*, 171, pp. 487-494.

Hammami, R., Y. Frein, and B. Bahli. (2017) 'Supply Chain Design to Guarantee Quoted Lead Time and Inventory Replenishment: Model and Insights', *International Journal of Production Research*, 55(12), pp. 3431–3450.

Harrison TP (2005) 'Principles for the strategic design of supply chains', In: Harrison TP, Lee HL, Neale JJ (eds) The practice of SCM. Kluwer Academic Publishers, Boston.

Hendricks, K.B. and Singhal, V.R. (2003) 'The effect of supply chain glitches on shareholder wealth', *Journal of Operations Management*, 21(5), pp. 501-22.

Hirsjärvi, S., Hurme, H. (2001) 'Tutkimus-haastattelu, teemahaastattelun teoria ja käytäntö'. Yliopistopaino, Helsinki.

Hirsjärvi, S., Remes, P. & Sajavaara, P. (2004) 'Tutki ja kirjoita'. Helsinki: Tammi.

Inman, R., Bhaskaran, S. (2019) 'Empirical evaluation of the delivery risk of extended supply chains', *International Journal of Production Research*, 57(11), pp. 3466-3477.

Inman, R. R., and D. E. Blumenfeld. (2014) 'Product Complexity and Supply Chain Design', *International Journal of Production Research*, 52(7), pp. 1956–1969.

Ivanov, D. (2018) 'Structural Dynamics and Resilience in Supply Chain Risk Management', Cham: Springer International Publishing.

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*, 136.

Ivanov, D. (2021) 'Supply chain risks, disruptions, and ripple effect', Introduction to Supply Chain Resilience, Springer International Publishing, Cham, pp. 1-28.

Kern, D., Moser, R., Hartmann, E., Moder, M. (2012) 'Supply risk management: model development and empirical analysis', *International Journal of Physical Distribution & Logistics Management*, 42(1), pp. 60-82.

Kleindorfer, P., Saad, G. (2005) 'Managing Disruption Risks in Supply Chains', *Production and Operations Management*, 14(1), pp. 53-68.

Kleindorfer, P. R., Van Wassenhove, L. (2004) 'Risk management for global supply chains: An overview in The Alliance on Globalizing', Chapter 12. H. Gatignon, J. Kimberly (eds.). Cambridge University Press, Cambridge, Massachusetts.

Knox, B. (2023) 'Navigating Electrical Supply Chain Issues as a Small Contractor', [Online] Available at: https://www.raiven.com/blog/navigating-electrical-supply-chain-issues-as-a-small-contractor (Accessed: 18.10.2023).

Koplin, J., Seuring, S., Mesterharm, M. (2007) 'Incorporating sustainability into supply management in the automotive industry – the case of the Volkswagen AG', J. Clean. Prod., 15(11–12), pp. 1053–1062.

Kowalczyk, A. (2017). Forrester's effect. Bullwhip effect. *World Scientific News*, (78), 209-212.

Krippendorff, K. (2019) 'Content analysis: an introduction to its methodology'. Los Angeles, CA: SAGE Publications, Inc.

Lee, Jade Man-yin, and Eugene Yin-cheung Wong. (2021) "Suez Canal Blockage: An Analysis of Legal Impact, Risks and Liabilities to the Global Supply Chain." *MATEC Web of Conferences* 339 (2021): 1019-. Web.

Lin, Y. K., C. F. Huang, Y. C. Liao, and C. C. Yeh. (2017) 'System Reliability for a Multistate Intermodal Logistics Network with Time Windows', *International Journal of Production Research*, 55(7), pp. 1957–1969.

Lo, G. Marcelin, I. Bassène, T. Sène, B. (2022). "The Russo-Ukrainian War and Financial Markets: The Role of Dependence on Russian Commodities." *Finance research letters* 50 (2022): 103194-. Web.

Lonsdale, C. (1999) 'Effective managing vertical supply relationships: a risk management model for outsourcing', *Supply Chain Management: An International Journal*, 4(4), pp. 176–183.

Narasimhan, .Talluri, . (2009) 'Perspectives on risk management in supply chains', *Journal of Operations Management*, 27, pp. 114–118.

NASDAQ OMX's News Release Distribution Channel. (2021) 'Electrical Equipment Global Market Report 2021: COVID 19 Impact and Recovery to 2030: Major companies in the electrical equipment market include Panasonic Corporation; Samsung Electronics Co Ltd; ABB Ltd; Sumitomo Electric Industries Ltd and Toshiba Corporation', New York: NASDAQ OMX Corporate Solutions, Inc.

Neiger, D. Rotaru, K. and Churilov, L. (2009). "Supply Chain Risk Identification with Value-Focused Process Engineering." *Journal of operations management* 27.2 (2009): 154–168.

Norrman, A., Jansson, U. (2004) 'Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident', *International Journal of Physical Distribution & Logistics Management*, 34(5), pp. 434–456.

Manuj, I., & Mentzer, J. T. (2008) 'Global supply chain risk management strategies', *International Journal of Physical Distribution & Logistics Management*, 38(3), pp. 192-223.

Mehrjoo, M., and Z. J. Pasek. (2016) 'Risk Assessment for the Supply Chain of Fast Fashion Apparel Industry: A System Dynamics Framework', *International Journal of Production Research*, 54(1), pp. 28–48.

Metsämuuronen, J. (2005) 'Tutkimuksen tekemisen perusteet ihmistieteissä'. Gummerus Kirjapaino Oy, Jyväskylä.

Mital, M., Del Giudice, M., Papa, A. (2018) 'Comparing supply chain risks for multiple product categories with cognitive mapping and Analytic Hierarchy Process', Technological Forecasting & Social Change, 131, pp. 159-170.

Mohr, Susanna et al. (2023). "A Multi-Disciplinary Analysis of the Exceptional Flood Event of July 2021 in Central Europe – Part 1: Event Description and Analysis." *Natural hazards and earth system sciences* 23.2 (2023): 525–551. Web.

Olson, David Louis. (2014) *Supply Chain Risk Management: Tools for Analysis*. Second edition. New York, New York (222 East 46th Street, New York, NY 10017): Business Expert Press, 2014. Print.

Poutvaara, P., Rhode, C., Stiiieneder, T. & Valeyatheepillay, M. (2019) 'Contribution to Growth: Free Movements of Goods Delivering Economic Benefits for Citizens and Businesses'.

Rajesh, R., Ravi, V., Venkata Rao, R. (2015) 'Selection of risk mitigation strategy in electronic supply chains using grey theory and digraph-matrix approaches', *International Journal of Production Research*, 53(1), pp. 238-257.

Richert, M., Dudek, M. (2023) 'Risk Mapping: Ranking and Analysis of Selected, Key Risk in Supply Chains', *Journal of Risk and Financial Management*, 16(2), p. 71.

Steele, P., Court, B. (1996) 'Profitable Purchasing Strategies: A Manager's Guide for Improving Organizational Competitiveness Through the Skills of Purchasing'. McGraw-Hill, London.

Tang, O., & Musa, S. N. (2011) 'Identifying risk issues and research advancements in supply chain risk management', *International Journal of Production Economics*, 133(1), pp. 25-34.

Thun, J. H., and D. Hoenig. (2011) 'An Empirical Analysis of Supply Chain Risk Management in the German Automotive Industry', *International Journal of Production Economics*, 131(1), pp. 242–249.

Tomlin, B. (2006) 'On the value of mitigation and contingency strategies for managing supply chain disruption risks', Management Science, 52(5), pp. 639-57.

Treleven, M., Schweikhart, S.B. (1988) 'A risk/benefit analysis of sourcing strategies: single vs. multiple sourcing', *Journal of Operations Management*, 7(3–4), pp. 93–114.

Vilko, J. P. P., and J. M. Hallikas. (2012) 'Risk Assessment in Multimodal Supply Chains', *International Journal of Production Economics*, 140, pp. 586–595.

Wannenwetsch, H. (2005) 'Vernetztes supply chain management'. Springer, Berlin.

Zsidisin, G.A., Panelli, A., Upton, R. (2000) 'Purchasing organization involvement in risk assessments, contingency plans, and risk management: an exploratory study', Supply Chain Management: *An International Journal*, 5(4), pp. 187–198.

Zsidisin, G.A., Ellram, L.M., Carter, J.R. and Cavinato, J.L. (2004) 'An analysis of supply risk assessment techniques', *International Journal of Physical Distribution & Logistics Management*, 34(5), pp. 397-413.

Appendices

Appendix 1: Questionnaire for Companies:

1) The specific characteristics of the industry

A. How do electrical equipment companies assess and prioritise different types of disruption risks, such as natural disasters, geopolitical events or economic downturns?

B. How has the COVID-19 pandemic affected your approach to risk management and supply chain resilience, and what lessons have you learned from this experience?

C. What data and information do you collect and analyse to monitor and anticipate supply chain disruption risks?

D. How are companies adapting their risk management strategies and tools in response to changing market dynamics and new threats to the supply chain?

2) What problems have been identified?

A. Can you describe specific examples of supply chain disruptions experienced by the electrical equipment sector in recent years? How were these disruptions managed?

B. Which components are the main targets of these availability risks?

3) What the consequences of the problems have been?

A. What are the key challenges and vulnerabilities that B2B electrical supply chains face in terms of disruption and availability risks?

4) How the problems are now being addressed and any plans for future risk reduction?

A. What strategies and best practices have proven to be effective in mitigating disruption risks in B2B EE supply chains?

B. How do information systems and technology play a role in improving resilience and predictability of B2B electricity supply chains?

C. Can you give examples of risk management tools or methodologies that have been successfully implemented to address disruption and availability risks in electrical equipment supply chains?

D. To what extent do companies collaborate with their suppliers, customers and other stakeholders to proactively manage disruption risks? What are the benefits and challenges of such cooperation?

E. What role does inventory management play in managing disruption risks in B2B supply chains for electrical equipment? How do companies strike a balance between keeping surplus stock and maintaining efficiency?

F. What role does communication and transparency play in your relationships with customers and other supply chain partners in managing disruption risks?

G. How do you ensure that your suppliers also actively manage and mitigate disruption risks to avoid downstream impacts on your supply chain?

Appendix 2: Risk Assessment Matrix Questionnaire

Instructions: Please rate each of the following risks in terms of both likelihood and impact on a scale of 1 to 5, with 1 being the lowest and 5 being the highest. Probability refers to the likelihood of a risk materialising, while impact measures the severity of its consequences.

Availability risks:

1. Delivery time of the supplier:

- Probability (1-5):

- Impact (1-5):

2. Supplier reliability:

- Probability (1-5):

- Impact (1-5):

3. Transport and logistics delays:

- Probability (1-5):

- Impact (1-5):

4. Stock shortages:

- Probability (1-5):

- Impact (1-5):

5. Natural disasters (e.g. earthquakes, hurricanes) affecting suppliers or transport routes:

- Probability (1-5):

- Impact (1-5):

6. Technological disruptions (e.g. system failures, security breaches) affecting availability:

- Probability (1-5):

- Impact (1-5):

7. Policy or regulatory changes affecting imports/exports:

- Likelihood (1-5):

- Impact (1-5):

8. Financial stability of the supplier:

- Probability (1-5):

- Impact (1-5):

9. Quality control problems leading to production delays:

- Probability (1-5):

- Impact (1-5):

10. Labor disputes affecting the supplier's or manufacturer's workforce:

- Probability (1-5):

- Impact (1-5):

11. Global economic conditions affecting the supply chain:

- Probability (1-5):

- Impact (1-5):

12. Fluctuations in transport costs:

- Probability (1-5):

- Impact (1-5):