



## **Berlin School of Economics and Law**

Department of Business and Economics

### **“Identification and analysis of traditional and non-traditional measures to strengthen the risk resilience of supply chains in the Corona Pandemic 2020”**

A thesis submitted in fulfilment of the requirements for the degree of  
Bachelor of Arts

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# Contents

1	Introduction .....	1
2	Literature review.....	2
2.1	Supply chain.....	3
2.2	Supply chain risk management .....	6
2.3	Supply chain resilience framework.....	9
2.3.1	Traditional proactive measures .....	11
2.3.2	Traditional reactive measures .....	13
2.3.3	Traditional proactive and reactive measures .....	14
2.4	Summary and discussion of the literature review .....	14
3	COVID-19 global pandemic: Introduction of the contextual frame of reference .....	17
4	Methodology.....	19
4.1	Sampling.....	20
4.2	Data collection.....	21
4.3	Data analysis .....	22
5	Single case descriptions.....	22
5.1	Company A .....	22
5.2	Company B.....	25
5.3	Company C.....	28
5.4	Company D .....	30
6	Cross case analysis .....	32
6.1	Analysis of empirically identified risk mitigation measures.....	34
6.1.1	General crisis management.....	35
6.1.2	Information management.....	36
6.1.3	Supply and transport .....	37
6.1.4	Production and operations .....	37
6.1.5	Demand.....	38
6.2	Analysis of pandemic-specific factors .....	39
7	Conclusion.....	42
8	Literature .....	44
9	List of Figures.....	50
10	Appendix.....	51

## 1 Introduction

The starting point of this thesis is based upon the most recent epidemic crisis, caused by the coronavirus SARS-CoV-2 (COVID-19) in the beginning of 2020. Companies worldwide are under enormous pressure and existential threat. The global pandemic has largely reached all parts of the world and poses an unprecedented challenge for internationally operating companies. The complete shutdown of normal operations, production stops, supply shortages, disruptions in distribution, for example, through border closures or export restrictions, fluctuations in demand and supply - these are all exemplary consequences caused during the corona crisis (Ivanov and Das, 2020). All the examples mentioned have at least one thing in common: they all represent a disruption of the supply chain (SC) of a company. They impede material flows and affect the coordination and cooperation between suppliers, manufacturers, distributors and customers. Such disruptive events can be very disastrous for companies. For example, after the earthquake in Japan in 2011, companies in the disaster area suffered declines in annual sales of 4.8% on average in the following year (Carvalho et al., 2016).

Companies can usually only recover from such events if they have taken adequate risk prevention measures in advance, are flexible and act in a structured way during the crisis to stabilise the situation (Ivanov et al., 2019, pp. 466-469), and have sufficient financial reserves and resources to survive the crisis and prevent insolvency (Harbour, 2020).

Since SC disturbances can have such serious effects on companies, risk management of SCs has received increasing attention over the last decades. In the academic literature, two categories of disturbances are distinguished. The first category includes the frequently occurring operational disturbances, for example, daily/weekly fluctuations in demand that are referred to as the bullwhip effect. These disturbances tend to have minor impacts on SCs. The second category includes the extraordinary, random and rarely occurring disruptions, for example, natural disasters, fires in production halls, etc., which have more serious impacts (Ivanov et al., 2019, pp. 462-464). Such events represent examples of causes of the so-called ripple effect, which describes the downstream propagation of a disruption within the SC (Ivanov 2018, pp. 34-35). The pandemic is also among the triggers of the ripple effect, although some characteristics are very specific (Ivanov 2020).

Epidemic outbreaks are considered special cases of SC disruptions for three reasons. First, because of the long-lasting existence and the unpredictable extent of the SC disturbance. Second, because of the simultaneous propagation of the disruption along the global SC and the spread of the virus in the population. Third, because of the simultaneous effect of the disorder on supply, demand and transport (Ivanov 2020). Therefore, it seems necessary to review traditional risk management methods for their suitability during the pandemic, to adapt them to the requirements of the pandemic and to identify possible new measures for risk mitigation and crisis management.

The aim of this work was to investigate which methods were applied by companies in Germany during the COVID-19 pandemic to mitigate SC risks, compensate for the negative effects of the crisis and ultimately ensure the survival of the company. It should be investigated whether the SC risk mitigation methods applied are consistent with the ideal forms from the literature (traditional measures) and whether new, previously undiscussed methods (non-traditional measures) have been applied during the current crisis. On the one hand, this serves the purpose of drawing conclusions on the application and suitability of traditional methods in

the case of pandemics and possibly expanding the state of research by identifying potential non-traditional methods. On the other hand, the evaluation of the findings should provide practice-relevant information that companies can consider in the event of pandemics in the future.

Therefore, the research question of this thesis is:

"Which traditional and non-traditional, supply chain risk mitigation measures were applied by companies during the corona pandemic in Germany?"

The scope of the work is thus limited to a specific scenario (corona pandemic from early 2020 to August 2020), a specific political and geographical environment (Germany), a variety of decision-makers (companies), an organisational field (supply chain management), a specific area (risk management) and specific factors within this area (traditional and non-traditional measures).

The structure of the study is based on a literature review that provides the relevant theoretical foundations, identifies and explains the methods of SC risk management discussed in the literature, and thus creates a framework for a later comparison between theory and practice. This is followed by a description of the COVID-19 pandemic to introduce the reader to the context and framework of the study. The next part explains the method used to answer the research question and why it was considered appropriate for this study. In this respect, qualitative research was carried out in the form of multiple case studies in order to gain in-depth insights into practice. For this purpose, four expert interviews were conducted with suitable candidates from different German companies in order to collect data for the evaluation. After a presentation of the interviewees and companies, the analysis starts with the single-case descriptions. The results are then compared and evaluated using a cross-case analysis. This serves the objective of showing which methods have been used in practice and in which form, how successfully they have been applied in different situations and companies, and which practical conclusions have been drawn with regard to the risk management of SCs in the face of pandemics. Ultimately, the findings are summarised and presented in the conclusion, providing the reader with the key findings of this study and potential future research avenues.

## **2 Literature review**

This part contains all relevant definitions and explanations, which form the theoretical foundation for this study. It starts with a basic definition about SCs (Chapter 2.1), including the relevant functions and explaining some important terms and characteristics. In this regard, some theoretical concepts such as the value creation process, the characteristics of SCs, and the relationships between members of the SC are explained. However, the focus of this study lies on risk management in SCs (Chapter 2.2) and the SC resilience framework (Chapter 2.3). Therefore, in chapter 2.2 relevant terms for the proper understanding of this study are defined, such as risk, uncertainty and disturbance. Here, the pandemic is also classified with regards to the existing risk categories. In addition, some examples of serious supply chain disruptions from the past are given and the different phases of such disruptions are explained. Chapter 2.3 presents the SC resilience framework and explains the relevant terms and concepts behind the idea. It comprises all risk mitigation measure categories that were found during the literature review and gives examples for concrete measures. The findings are discussed at the end of the chapter and, at this point, assumptions are made about what is expected from the empirical research.

## 2.1 Supply chain

In the literature there are many different interpretations of what a SC is and how it can be defined (Biedermann 2018, pp. 17-24). Following Otto (2002), Biedermann demonstrates different approaches of SC definitions. The first approach is based on the principle of added value. Following this view, the term SC can be used synonymously with value chain. Kim (2018, pp. 3-22) summarises the main aspects of the concept of a value chain (Fig.1) that was originally established by Michael Porter (“Competitive Advantage”, 1985). Summarising Porter’s idea, Kim states that a firm must perform primary functions such as inbound logistics (bringing raw material into the firm), operations (transforming inputs such as raw material, into outputs such as final products), outbound logistics (bringing these products to the customer), marketing and sales (promoting these products to the customer), and services (after sales service, maintenance, etc.), to create value for the customer. Furthermore, so called support activities exist to improve a firm's efficiency. They include infrastructure (IT, transportation), Human Resource Management (HRM), Research and Development (R&D) (developing new products), and procurement (buying inputs for operations, finding vendors, negotiating contracts and prices).

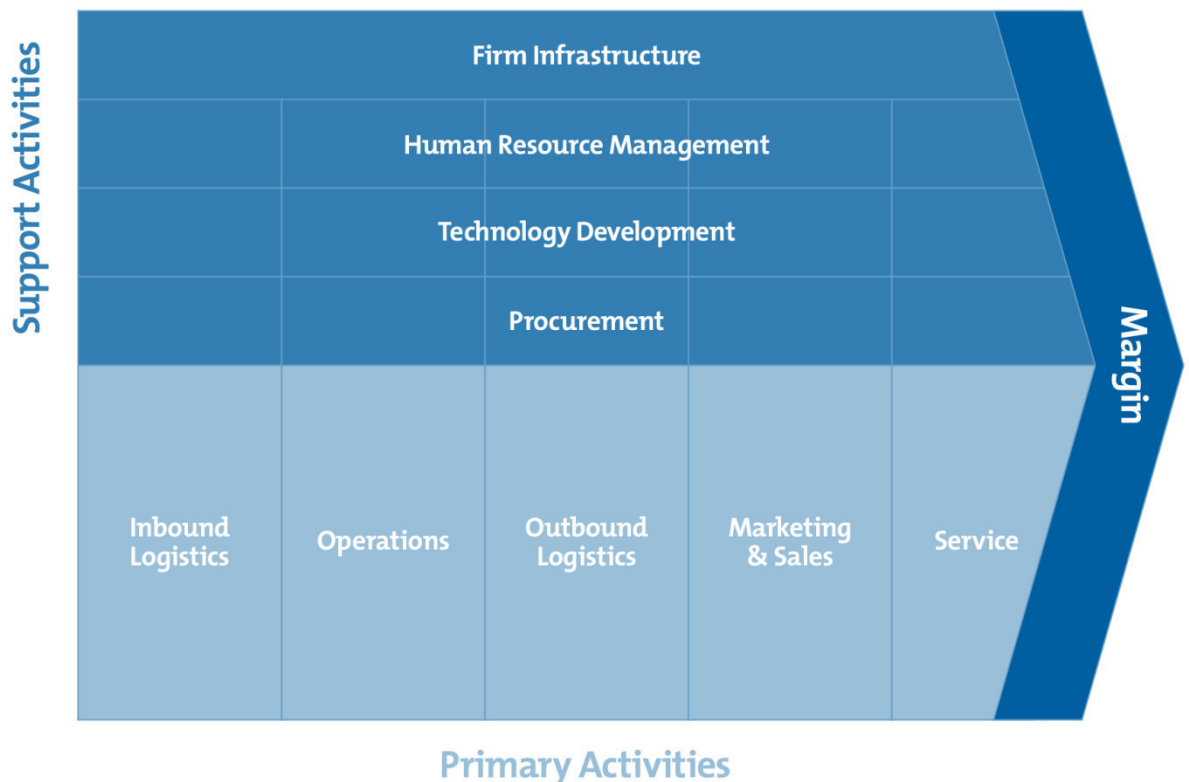


Fig. 1 Michael Porter’s Value Chain (Mind Tools (2020))

However, this definition of a SC is insufficient as it only describes the internal SC aspects of one firm. In another definition of a SC, Nakano (2020, pp. 3-18) distinguishes between internal and external aspects. While this expands the understanding of the SC by external processes, it is inadequate to consider a company in isolation, since there exist correlations with other companies in almost all areas and thus dependencies arise. Therefore, the second approach that Biedermann describes is more suitable. It says that a SC is a network of many different companies interacting with each other to create added value for customers (Biedermann 2018, p. 24). According to Ivanov et al. (2019, p. 7), a SC is best described as a network

“[...] of organizations and processes wherein a number of various enterprises (suppliers, manufacturers, distributors and retailers) collaborate (cooperate and coordinate) along the entire value chain to acquire raw materials, to convert these raw materials into specified final products, and to deliver these final products to customers”

This definition is considered as most suitable for this thesis, since it comprises all the important parties, actions, and nodes of a SC and takes the interdependencies of the enterprises during the value creation process into account. Fig. 2 shows an example of a SC. In theory, enterprises are linked vertically by contract (Biedermann 2018, pp. 18-19). For example, the producer orders metal from his supplier in order to build cars. As one can see in Fig.2 there exist different flows of material, energy, information and financials in a SC. We can use these flows as examples to explain the meaning of downstream (see material flow) and upstream (see information, financial flow). Whether an enterprise is localised upstream or downstream depends on the starting point., i.e. a supplier links downstream to the producer, the distributor, the retailer and the customers. On the other hand, a retailer links upstream to the distributor, the producer and the supplier (Nakano 2020, pp. 3-18). It is important to understand these terms when it comes to discussing the impacts of certain events and how they affect either upstream or downstream parts (or both) of the SC.

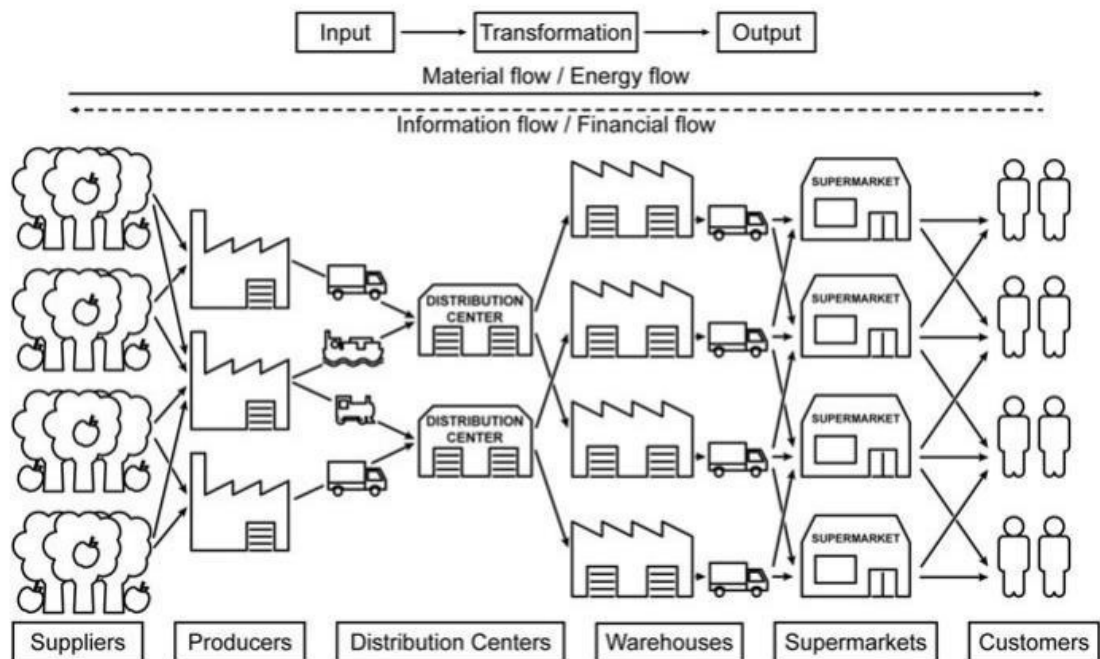


Fig. 2 Supply Chain (Ivanov et. al 2019, p.8)

Braun (2012, pp. 14-15) has identified several key features that characterise SC management (SCM). The first essential aspect, which is also mentioned by Ivanov et. al (2019, p. 7), is the cross-company and cross-functional role of supply chain management. This includes the optimal coordination of information, financial and material flows. Second, Braun names the long-lasting collaboration between the parties in a SC and indicates that SCM is about strategic alliances that go beyond a one-time business exchange and rather aims at long-term partnerships. He also mentions the intention of the companies to achieve a higher degree of target achievement. Finally, he explains that the approach to supply chain management is based

on the optimization of process flows, which results from the nature of a SC, namely its information and material flows. Therefore, SCM leads to a shift from the traditional view of the individual performance of functional areas, for example, purchasing, production, and sales, to the alignment of all activities towards customer satisfaction. The goal of SCM, is to efficiently and effectively create value for the customers. Effective SCM means being able to fulfil the customer's demand. Efficient SCM means the profitable utilization of resources (Heckmann 2016, p. 56). For a customer, value can be defined as a function of utility and costs. Therefore, value is a subjective concept which is difficult to measure, since every customer has slightly different preferences (Kim 2018, pp 3-22). It is consequently essential for every company to identify the needs of its customers since this knowledge can be used to determine which strategy a company should pursue, and which processes are ultimately value-adding or wasteful. The focus on value-adding activities and eliminating waste leads to a higher efficiency and effectiveness (Ivanov et al. 2019, p. 6). The SCM strategy is ideally matched with the overall competitive strategy of an enterprise which is called 'strategic fit' (Chopra and Meindl 2015, p. 21). Four basic competitive factors are costs, flexibility, time and quality. The balance of these factors strongly depends on the chosen strategy. The two main strategies of SCM are the efficient SC and the responsive SC (Fig. 3).

	<b>Efficient SC</b>	<b>Responsive SC</b>
<b>Primary purpose</b>	Supply predictable demand at lowest cost	Respond quickly to unpredictable demand
<b>Manufacturing purpose</b>	Maintain high average utilization rate	Deploy excess buffer capacity
<b>Inventory strategy</b>	Generate high turns and minimize inventory	Deploy significant buffer stocks/parts/finished goods
<b>Lead-Time focus</b>	Shorten lead time without increasing costs	Shorten lead time even at the expense of costs
<b>Supplier selection</b>	Select primarily for cost and quality	Select primarily for speed, flexibility and quality
<b>Product-design strategy</b>	Maximize performance, minimize cost	Modular design to allow postponement of product differentiation

Fig.3 Efficient vs Responsive Supply Chain (Fisher 1997, p.108)

Summarising Fig. 3, it can be stated that efficient SCs are appropriate when the price of the product is essential, i.e. the cost pressure is correspondingly high. On the other hand, responsive SCs make sense when the ability to deliver is crucial and the costs are rather marginal (Chopra 2019). Further information on general SCM can be found in Chopra (2019) and Ivanov et al. (2019). In the following section, this work deals specifically with the subject of risk management in SCs.



## 2.2 Supply chain risk management

According to Ivanov et al. (2019, pp. 456-464), supply chain managers spend about half of their working time dealing with risks and uncertainties, thus underlining their importance for risk management. Following this view, the two terms are defined in this chapter.

*Uncertainty* describes the lack of perfect information. The lack of perfect information is a situation where possible developments of the initial situation and the effects of various decisions may be known, but one does not know with what probability these developments will occur. This means that the actual consequences of a decision are not known, because the course of the initial situation is not predictable. Uncertainty is not necessarily negative as it holds both, the potential of risk but also chance. (Knight 1921, Wittmann 1959, Ivanov 2018, p. 19).

*Risk* is a situation of uncertainty that has a certain probability of having negative effects on a system. In SCM such probabilities are often unknown and therefore risk is used as a synonym for vulnerable which indicates how susceptible the system is to disturbances (Christopher and Peck 2004). Heckmann (2016, pp. 43-75) developed a definition of SC risk that includes the risk characteristics most frequently cited in the literature and provides a comprehensive framework for this study (see Fig 4).

According to Heckmann, the SC risk is subject to different characteristics. First, the *risk objective* describes the balancing act between effectiveness and efficiency objectives, which always threatens the company if it is not able to achieve both objectives. *Risk exposition* describes the occurrence of risk in relation to the cause-and-effect interaction or "triggering events" that cause a disruption. It also describes how vulnerable an SC is to such events and includes the relevance of time aspects in risk management. Finally, risk is perceived differently by each person, thus the subjective *risk attitude* of decision makers plays an important role in risk management.

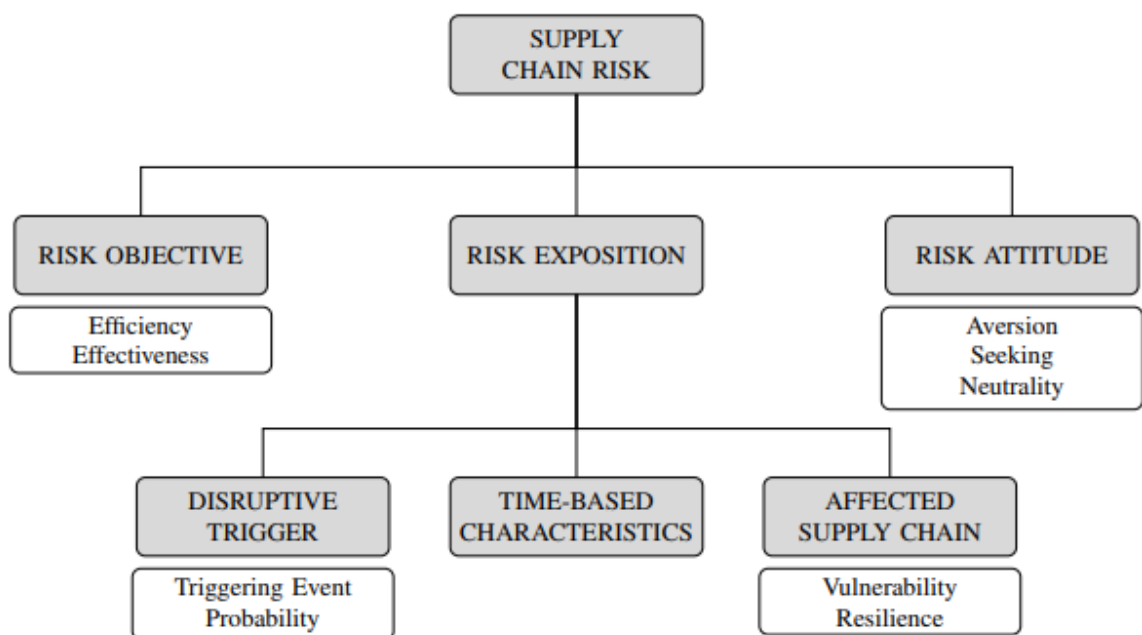


Fig. 4 Supply chain risk characteristics (Heckmann 2016, p. 52)

Similar to Wagner and Bode (2006), risk in the context of this work should be regarded as an exclusively negative aspect of the system. Although, as described above, uncertainty always offers a potential for opportunities and consequently winners may emerge from crises, this thesis focuses on measures to avoid and mitigate the negative aspects and therefore neglects the aspect of exploiting opportunities. Accordingly, it is assumed that managers do not rely on making profit from SC disruptions or even gamble on risk in order to realise competitive advantages.

Risk-based SC disturbances are extensively covered in the literature and a part of every SC. For this study, *disturbances* are defined as the realisation of risk and are therefore a deviation from the “normal” business operations (Biedermann 2018, p. 33, Ivanov et al. 2019, p. 457, Ivanov 2018, pp. 19-20, Blackhurst et al. 2011). Many authors have attempted to categorise risk to distinguish different types of risk. For example, Chopra and Sodhi (2004) categorise risk into disruption (due to natural disasters, terrorism) delay (due to high capacity utilisation, inflexible supply source) system (due to infrastructure failures), forecast (due to inaccuracy), intellectual property (due to outsourcing), procurement (due to single sourcing), receivables (due to the number of customers), inventory (due to product value, rate of product obsolescence), and capacity (due to inflexibility and cost) risks.

Although some further classifications of risk categories can be found in the literature (Ho et al. 2015, Heckmann 2016, Ivanov and Sokolov 2010, Quang and Hara 2017), they will not be discussed further in this thesis. Instead, the focus is on the category of disruption risk and how it differs from other risks. For this study, Klibi et al (2013) offer a suitable foundation for an appropriate risk classification. They distinguish random uncertainty (also referred to as recurrent, “normal”, business-as-usual or operational risks), hazard uncertainty (low frequency high impact events (see also: Ivanov et al. 2019a, pp. 1-2)), and deep uncertainty (lack of information about probable future outcomes, disruption risk). Random uncertainty is linked to operational risks that occur on a daily or weekly basis, for example demand and supply variations, which are more calculable and predictable. These are commonly associated with the term bullwhip effect (Ouyang and Li 2010). Hazard and deep uncertainty are linked to disruption risks that are caused by disasters, such as natural (hurricane, earthquake, wildfire, etc.) or man-made disasters (terrorism, war, diseases, economic policies) etc. and are therefore the focus of this work. These disruptions can have severe impacts on SCs and affect enterprises even in the long-term (Chiu and Choi 2016, Ivanov et al. 2019, pp. 463-466).

Craighead et al. (2007) define SC *disruptions* as “unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain”. There are many examples in literature, describing the impacts of various disasters. A well-known case study is the fire at the Philips microchip factory in March 2000. The factory supplied both Ericsson and Nokia. Ericsson suffered a loss of sales of 400 million US dollars because production came to a standstill due to the lack of supply (Chopra et al. 2007). Tang (2006) cites numerous other cases, such as the insolvency of one of Land Rover's key suppliers in 2001, which led to the layoff of 1400 Land Rover employees, or the decline in Dole's revenues after a hurricane destroyed its banana plantations in 1998. The effects of disruptive incidents can spread through the SC and may affect not only the company initially impacted but also any other SC member (Scheibe and Blackhurst 2017). The above-mentioned cases serve as illustrations of the serious consequences of these disruptions and their impact on various actors in the SC.

Two aggravating aspects, particularly in the case of risks of disruption, must also be considered. The first aspect is, that the affected businesses do not necessarily need to be located in the affected (geographical) area but may be indirectly affected by the repercussion effects (Scheibe and Blackhurst 2017). For instance, considering the current corona crisis, many companies worldwide have already reported supply shortages even before the virus has spread beyond China. The second aspect is, that decisions taken internally by the company itself, and externally by partners or governments, after the occurrence of a disruption can also strongly influence the severity of the impacts on businesses. For example, political decisions on measures to protect public health have in most cases worsened the economic situation of businesses during the corona pandemic, which also demonstrates the implications of subsequent effects of a disruption (Wagner and Bode 2006). Two terms commonly used in the literature to describe the phenomenon of the two aspects mentioned are SC disruption propagation and the ripple effect in the SC, whereas former one can be defined “as the spread of the disruption effects beyond the initial disruption location” (Scheibe and Blackhurst 2017) and latter one “as a disruption that cannot be localized and cascades downstream impacting supply chain performance” (Ivanov et al. 2019, pp.464-465, Ivanov 2018, pp. 34-35).

As SC networks are constantly exposed to uncertainty and risk, with continuously changing parameters, various authors (Biedermann 2018, Ivanov 2018, Scheibe and Blackhurst 2017) stretch the importance of a dynamic approach to SC risk management. The logic behind this approach is that not only SCs but also the risks that have been identified are dynamic in nature. This implies that the measures to control and mitigate these risks must be dynamic and flexible too, to respond as appropriately as possible to the risk situation.

Ultimately, the disruption characteristics must be explained. Biedermann (2018, pp. 50-57) names three aspects of disruptions that can help to differentiate them. Firstly, he mentions the importance of time aspects. Hohenstein et al (2015) have conducted a literature review on this matter and found that disruptions can be divided into four different phases: readiness, response, recovery, and growth (see Fig. 5). The pre-disruption situation (readiness) is referred to as business-as-usual situation during which companies can prepare for disruptions. Depending on the disruption, firms might have additional preparation time before the impact (early warning systems for storms, etc.), or they might be abruptly affected (terrorist attack). During the response phase, firms are trying to control the situation and prevent any further damage. The recovery phase comprises all actions aimed at returning to the “normal” operating levels (Pettit et al 2013). Note that firms time for recovery can easily take up to two years (Hendricks and Singhal 2005). Finally, the growth phase aims to achieve an even higher level of operation than before the disruption.

Secondly, based on Viswanadham and Gaonkar (2009) and L’Hermitte (2014), Biedermann names the specifications of disruptions as another characteristic for differentiation. This comprises probability of occurrence, causes and intensity of disruptions whereas intensity is divided into smaller deviations, disruptions and catastrophes, depending on severity. Range is the last aspect and distinguishes disruptions in terms of their propagation in the network. Kim et al (2015) differentiate between node (a single production facility, supplier, etc. is disabled), arc (transportation between two nodes is shut down) and network level disruptions (the material flow between supplier and customer is completely interrupted).

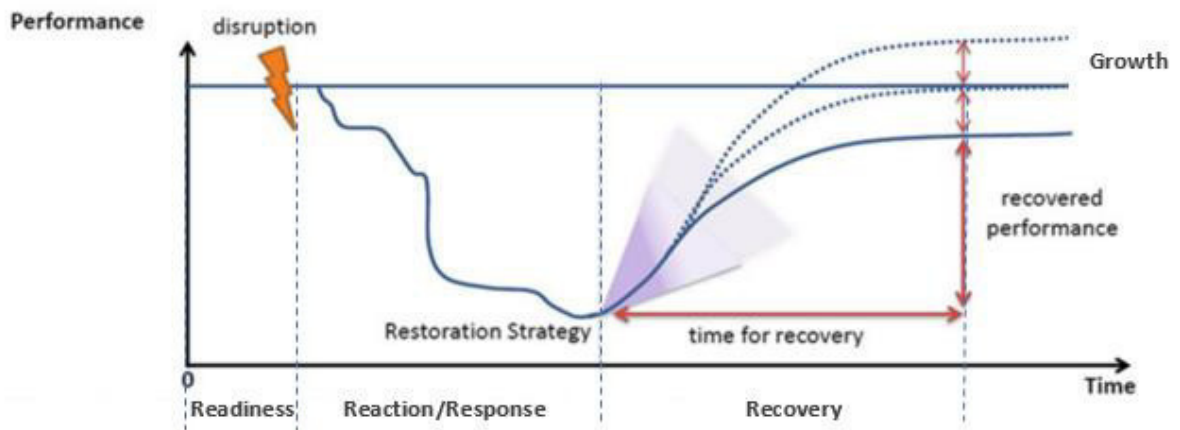


Fig. 5 Phases of disruptions and performance analysis (adopted from Ivanov 2018, p. 52)

An understanding of the above-mentioned aspects forms a foundation for this work, as they are referred to in the elaboration and description of various risk management measures. Disruptions can have severe negative consequences and can sometimes force companies into insolvency. Traditional risk management methods, which allow companies to calculate the probabilities of different scenarios and then compare the expected profit with the potential risks, are inadequate in view of the unpredictability and uncertainty associated with disruption risks (Pettit et al 2010). It is therefore necessary for companies to address the concept of supply chain resilience as a supplement to their risk management in order to effectively manage these incidents and their consequences and ensure the continuity of the company. Therefore, the next section presents the SC resilience framework and explains the underlying concepts.

### 2.3 Supply chain resilience framework

In the context of this thesis, an understanding of SC resilience can be defined as follows: “SC resilience manifests when the network is capable to withstand, adapt, and recover from disruptions to meet customer demand and ensure performance” (Hosseini et al. 2019).

Numerous interrelated reasons why SC resilience is relevant for firms were found. The liberalisation of international trade and globalisation has lengthened companies' supply chains and increased their complexity, making them less transparent and more difficult to control. In conjunction with technological change, which shortens product life cycles and increases the speed of innovation, and volatile markets that are becoming increasingly unpredictable, the business environment has become more dynamic and turbulent. Due to intensified competition and customer orientation, companies are increasingly exposed to cost pressure and are therefore relying on more efficient strategies such as lean management, outsourcing and a reduced supplier base, etc. as well as on methods to improve customer service, for example by offering a greater variety of products or shorter delivery times. That increases the interdependencies of companies and the complexity of SCs, thus raising their vulnerability to risks (Kim et al. 2015 Gao et al. 2019, Pettit et al. 2013, Christopher and Peck 2004, Bode et al. 2011, Chopra and Sodhi 2014, Ambulkar et al. 2015, Biedermann 2018, pp. 1-3, Fan and Stevenson 2018, Dubey et al. 2019, Scheibe and Blackhurst 2017, Blackhurst et al. 2011, Ivanov and Dolgui 2020, Araz et al. 2020). Consequently, the frequency of occurrence and the costs of disruptions have increased dramatically over the last two decades (Tang 2006, Gupta et al 2016).

In the academic literature and research on supply chain resilience there is no uniformity of terminology. Biedermann (2018) as well as Kim et al. (2015) provide extensive literature analyses and definition comparisons that prove this lack of coherence. Due to the brevity of this paper, a detailed analysis of the various existing terms and definitions will be omitted. Therefore, working definitions are used that were considered appropriate in the context of this study. The process of finding an appropriate definition is presented in the following section.

Kim et al (2015) have compared different definitions and approaches to SC resilience in their literature review. They found that there is no clear definition in academic literature that is commonly recognized and referred to. The core statements of the literature review on SC resilience can be related to the phases of a disruption (see Fig. 5), since SC resilience comprises a proactive (pre-disruption) and a reactive part (post-disruption). According to several authors (Christopher and Peck 2004, Scholten et al. 2014, Tang 2006, Sheffi and Rice 2005, Craighead et al. 2007, Biedermann 2018, p. 49), SC resilience involves preparation for, resistance to, recovery from, and growth after a disruption. SC resilience is often perceived as the ability of a company to master the above-mentioned steps and treated as a specific form of SC design that ideally works in both business-as-usual and crisis situations (Pettit et al 2010, Blackhurst et al 2011). In the academic literature, the numerous methods mentioned for enhancing the resilience of companies are divided into two larger categories: the *resource-based* methods and the *adaptive* methods (Biedermann 2018, pp. 46-47).

In the event of a disruption, the former one is designed to return to a stable situation by previously placed additional resources along the SC and their (re-)allocation. This category is often termed *robustness* of SCs “which characterises the ability to perform planned execution under disturbances” (Ivanov 2018, p. 59). Thus, robustness focuses on the pre-disruption phase but also offers capabilities that the company can utilise during the response phase (Ivanov et al 2019a, p.10) In this sense, robustness can be distinguished from the holistic concept of SC resilience, which also comprises the post-disruption recovery of the company's performance after being affected (Ivanov et al. 2019, p. 467).

The latter category includes the ability of a company to react to unforeseen disruptions, to adapt to them and thus to recover from the deviation in its operations. It includes, for example, the quick flow of information between companies, postponement of product customization and flexible use of facilities. This category is often referred to as *flexibility* of a company's SC which “is a property concerning its ability to change itself quickly, structurally and functionally depending on the current execution state and reaching supply chain management goals by a change in supply chain structures and behaviour” (Ivanov et al. 2019, p. 469).

According to Ivanov et al. (2019a, pp. 10-11) SC resilience is based upon *redundancies* that create both robustness and flexibility, whereas robustness is rather associated with the proactive planning stage and flexibility rather with the reactive execution stage of disruption mitigation management. This study follows this approach as it best summarises and logically explains the various views found in the literature review.

In the event of serious disruptions, the survival of companies is threatened. In such cases, the importance of viability is emphasized. This shifts the focus away from the pure pursuit of profit and the generation of most revenues to the preservation of the company and the supply of products and services to the population. Viability is described as the ability of a system “to maintain itself and recover in the presence of disturbances over a long-term horizon” (Ivanov

and Dolgui 2020). For this study, a SC risk management understanding will be applied that extends SC resilience through viability to address the context of COVID-19 as a severe disruption that threatens companies' survival.

The next section elaborates and lists the measures identified in the literature to enhance the resilience of SCs. These measures are referred to as "traditional measures" in the course of this work, as they represent the results of previous studies and experience.

### **2.3.1 Traditional proactive measures**

In this part, the proactive risk mitigation measures are presented, that were found in the literature.

The best known and widespread method for enhancing the robustness and thus the SC resilience seems to be the creation of redundancies along the SC. Redundancies are defined as excess capacity that increase the robustness of a SC in the event of a disruption (Biedermann 2018, pp. 129-130, Sheffi and Rice 2005). Examples for redundancies are excess production or transportation capacities, safety stocks, multiple sourcing, etc. (Tang 2006, Ivanov and Dolgui 2019, Sheffi 2005, Hosseini et al. 2019, Ivanov 2018, p. 36). In case of pandemics, Pettit et al (2013) also name financial strength, for example, in form of financial reserves to buffer potential cash flow disruptions, as a measure to enhance a firm's resilience. Although redundancies are regarded as a proven means of risk reduction, they are also associated with high costs and reduce operational efficiency in business-as-usual situations (Sheffi 2005). Another problem regarding the use of redundant capacities is concerned with the justification of such investments. Since managers usually have limited resources, they must allocate those resources in the optimal manner. Consequently, as disruptions may never actually occur or are difficult to predict firms cannot easily assess cost benefit calculations to justify investment into such risk mitigation measures so that at least in the past, the focus of companies was rather on efficient than resilient SC design (Tang 2006, Sodhi and Tang 2012, pp. 7-8).

Predefined contingency plans are another method discussed in the literature. They represent a standard protocol for the procedure in case of disruptions. Therefore, some authors recommend the development and practice of contingency plans in order to increase the reaction speed (velocity) of the company in case of an emergency (Blackhurst et al. 2011, Biedermann 2018, pp. 133-135, Pettit et al. 2010).

The culture of a company is also an often-mentioned characteristic of resilient SCs in academic literature (Biedermann 2018, pp. 141-142). The right corporate culture makes it possible to dedicate adequate attention to information about risks and to evaluate them in order to be able to act immediately in case of emergency (Sheffi and Rice 2005). It comprises top management support and leadership during disruptions, predefined guidelines for managers as well as communication protocols in case of emergencies (Ponomarov and Holcomb 2009, Christopher and Peck 2004, Hosseini et al. 2019). Regarding the context of culture, the common perception and awareness of possible SC threats among the partners is mentioned by Scholten et al (2014, p. 215) and Faisal (2006). Empowerment and accountability, training and qualification of employees is also named as a characteristic of the right culture (Sheffi 2005, Pettit et al. 2010). This should enable employees to come forth with creative solutions and passion for their work, even under the pressure of disruptions (Sheffi 2005, Biedermann 2018). Finally, the ability of the organisation to learn from past disasters and achieve a better state of

preparedness before the next disruption is important for resilient SCs (Ponomarov and Holcomb 2009)

The next proactive measure is network design and reconfiguration. Traditionally, supply chains are designed to be optimised in terms of efficiency (cost) and/or responsiveness (customer service). Resilience has rarely been the main target for the optimisation process (Christopher and Peck 2004). This means that firms need to incorporate resilience into their understanding and planning of SCs and be able to reconfigure it quickly during disruptions. Regarding the successful and "right" supply network design for companies, many authors have addressed the balance of resilient capacities and capabilities on the one hand and efficient and cost-effective operations on the other hand (Pettit et al 2010, Ivanov and Dolgui 2019, Christopher and Peck 2004, Tang 2006, Chopra and Sodhi 2014). Academic literature deals, for example, with the correlation between network density, complexity and criticality of nodes (Blackhurst et al. 2011, Kim et al. 2015) or with different approaches to the network structures, i.e. decentralisation, localization and segmentation of SCs (Chopra and Sodhi 2014, Ivanov and Dolgui 2019).

Another really important step towards SC resilience is real time monitoring and IT infrastructure that enables a company to track all the information, material and financial flows and can sometimes serve as an early warning system prior to disruptive events thus enabling companies to increase their reaction speed, i.e. velocity (Pettit et al. 2010, Biedermann 2018, p. 145).

Demand management is mentioned as another measure that is used during disruptions to smooth dynamic fluctuations in demand and match it to given capacity limits (Biedermann 2018, pp. 145-146). Sometimes, the supply in an industry is fixed and flexible sourcing strategies are not viable. This is when demand management is especially useful. In order to influence and manipulate customer choice companies can grant discounts on certain products or use dynamic pricing models. An example for demand management is given by Sodhi and Tang (2012, p. 53). They refer to the company Dell which was able to shift the customer demand from one product to another, thus improving its earnings by 41% even during a supply disruption in 1999.

Lastly, supplier management can help to enhance SC resilience and flexibility through tight collaboration and coordination with upstream suppliers, multiple sourcing and joint emergency plans (Biedermann 2018, pp. 147-148, Blackhurst et al. 2011). Again, an example for the importance of supplier management (in this case: multiple sourcing) is given by Sodhi and Tang (2012, p. 96). They refer to the year 1997 when the Indonesian rupiah was devalued by more than 50 % and many Indonesian suppliers were unable to pay for the imported components or materials, and therefore could not produce the finished articles for their US customers. At that time, Li and Fung, with a network of 4,000 suppliers throughout Asia, managed to transfer parts of the production from Indonesia to suppliers in other Asian countries. This enabled the company to overcome the negative impacts of the crisis.

This part has covered the top categories of traditional proactive measures to enhance the resilience of SCs identified during the literature review. The next section deals with reactive risk mitigation measures.

### 2.3.2 Traditional reactive measures

Probably the most important, best known and most discussed characteristic of resilient SCs is flexibility, defined as the ability that allows companies to take measures that enable rapid reaction and adaptation to disruptions. (Biedermann 2018, pp. 131-133). Flexibility paves the way for taking effective measures in the event of a crisis. There are many examples for flexibility in academic literature. Firstly, flexible transportation systems (short-term available forwarding and transport capacities, multi-modal transportation, multiple routes), production facilities (modular process and product design), resources (cross-trained staff, interchangeable parts and facilities) and labour arrangements (Biedermann 2018, pp. 131-133, Sheffi 2005, Sodhi and Tang 2012, pp. 100-101, Tang 2006). Furthermore, Pettit et al. (2013) name flexible supplier contracts and multiple sourcing as well as parts commonality and multiple use as factors of flexibility. Another popular strategy to increase flexibility is postponement (Tang 2006, Pettit et al. 2013, Ivanov and Dolgui 2019, Sheffi 2005, Ivanov 2018, p. 36). The "Postponement strategy utilises product or process design concepts such as standardisation, commonality, modular design and operations reversal, to delay the point of product differentiation" (Tang 2006, p. 38). This enables companies to shift semifinished products to the areas where they are needed most and to flexibly match supply with demand (Sheffi and Rice 2005). In addition, some authors emphasize that flexibility is the more profitable solution compared to robustness, as it saves the cost of, for example, redundant inventory, while at the same time providing competitive advantages through higher responsiveness under normal operating conditions (Sheffi and Rice 2005).

In connection with flexibility, the next characteristic, velocity, plays an important role. Velocity describes the reaction speed of SCs in case of disruptions (Biedermann 2018, pp. 133-135). Following Jüttner and Maklan (2011) and Smith (2004), Biedermann (2018, p. 133) takes the view that velocity tends to lead to efficiency gains, for example, by reducing lead times and the time from the impact of a disruption to the company's initial reaction. This shortens the time for recovery because reactive measures can be taken earlier, which in turn enables the company to quickly return to business-as-usual and possibly realise competitive advantages if competitors fail to take similar measures in time. Velocity can be enhanced through information transparency, predefined contingency plans and by reducing lead times (Scholten and Schilder 2015).

The third and last reactive measure identified is responsiveness. Responsiveness is the ability to identify and evaluate changes in the market and process information to take appropriate action. For a company to be responsive, it is important that information and material are flowing effectively and transparently. This can be achieved, for example, through postponement, the exchange of information between SC partners and cooperation in replenishment and forecasting (Biedermann 2018, pp. 135-137). Additionally, IT systems for real time monitoring of the SC are essential to track all the resources and to increase the ability to control the system (Sheffi and Rice 2005). In case of pandemics, Pettit et al. (2013) are also stretching the need for employee protection measures as a response to the potential of infections.

This section has listed the identified reactive risk mitigation measures and explained them. Some measures can be applied in both the proactive and the reactive phase and therefore cannot be accurately categorised. These measures are presented in the next section.



### 2.3.3 Traditional proactive and reactive measures

Measures that are applied both proactively as well as reactively include collaboration, information transparency and information sharing (Biedermann 2018, pp. 137-140).

Collaboration is defined as cross company ability to exchange information, to use resources, to communicate openly, to actively share knowledge and to make joint decisions based on aligned objectives and incentives (Biedermann 2018, pp. 137-138, Pettit et al 2013, Blackhurst et al 2011, Jüttner and Maklan 2011). Cao et al. (2010) name information exchange, common objectives and incentives for their achievement, partnership-based decision-making, shared use of resources, communication and joint knowledge management as factors that support successful collaboration. Pettit et al. (2013) also name the collaboration with governments as a mitigation measure that is especially useful during pandemics.

Information transparency or visibility can be defined as “knowledge of the status of operating assets and the environment” (Pettit et al. 2013). This factor contributes to the flexibility and velocity of a company by providing the information needed to make decisions under disruption (Mandal et al. 2016). Therefore, information transparency indirectly enhances the SC resilience (Blackhurst et al. 2011). It can be achieved, for example, through the implementation of IT software that tracks the important data about products, resources and employees. In this respect the use of tracking and tracing technologies is extremely useful (Ivanov et al. 2019a, pp. 314-315).

The last measure to enhance SC resilience that was identified during the literature review is the sharing of information between the SC partners. Through the exchange of information companies can mutually benefit as information is made transparent throughout the whole SC. This increases SC visibility and the responsiveness of the involved parties (Pettit et al. 2013, Mandal et al. 2016). In this context relevant data comprises, for example, information about potential disruptive events, customer demand, transportation problems, political changes, and potential risks (Biedermann 2018, p. 138-139).

This concludes the list of identified measures. The following chapter summarises the information and provides an overview of the measures.

## 2.4 Summary and discussion of the literature review

The insights gained from the literature were analysed and summarised in order to establish a reference framework for this work. All proactive and reactive risk management approaches that were identified in the literature and discussed in this study are summarized in Fig.6. For an in-depth list of examples for each of these measures see Pettit et al. (2013).

Characteristic	Measure	Description	Examples
Proactive	Redundancy	Excess capacity to increase the robustness of the supply chain in the event of a disruption event.	-Safety stocks -Free production/transport capacity -Multiple sourcing, etc.
	Predefined contingency plans	Standard protocol for the procedures in case of disruptions	-Development and practice of contingency plans

Characteristic	Measure	Description	Examples
	Culture and knowledge sharing	Foundation for the design of resilient supply chains	<ul style="list-style-type: none"> <li>-Top management support, guidelines, communication procedures</li> <li>-Common understanding and sensitivity for potential SC risks among partners</li> <li>-Training, qualification and empowerment of employees</li> <li>-Creative problem solving</li> <li>-Organizational learning, especially from previous disasters</li> <li>-Communication</li> </ul>
	Network design and re-configuration	Incorporate resilience in the planning stage of the SC design and be able to reconfigure it during disruptions	<ul style="list-style-type: none"> <li>-Balance of efficiency and resilience</li> <li>-Density</li> <li>-Complexity</li> <li>-criticality of nodes</li> </ul>
	Real time monitoring and IT infrastructure	Real time monitoring of material, information and financial flows enabled through IT systems	<ul style="list-style-type: none"> <li>-IT software</li> <li>-Increases velocity</li> <li>-Increases information transparency</li> </ul>
	Demand management	Manipulate customer demand to smooth dynamic fluctuations in demand and match them to given capacity limits	<ul style="list-style-type: none"> <li>-Discounts</li> <li>-Dynamic pricing</li> </ul>
	Supplier management	Upstream collaboration and alignment of incentives	<ul style="list-style-type: none"> <li>-Collaboration with suppliers</li> <li>-Multiple sourcing</li> </ul>
Reactive	Responsive-ness	Ability to detect and understand market movements in real time and to process information so that disruptive events can be compensated as quickly as possible	<p>Effective flow of information/ material and information transparency through:</p> <ul style="list-style-type: none"> <li>-Postponement</li> <li>-Information sharing among SC partners</li> <li>-Collaborative replenishment, forecasting</li> </ul>
	Velocity	Reaction speed of SCs in case of disruptions	<ul style="list-style-type: none"> <li>-Information transparency</li> <li>-Contingency plans</li> <li>-Quick turnaround time</li> </ul>

Characteristic	Measure	Description	Examples
	Flexibility	Ability that allows companies to take measures that enable rapid reaction and adaptation to disruptions	-Flexible transportation systems -Flexible production facilities -Flexible resources
Proactive and reactive	Collaboration	Cross company ability to exchange information, to use resources, to communicate openly, to actively share knowledge and to make joint decisions based on aligned objectives and incentives.	-Information exchange -Common objectives and incentives for their achievement -Partnership-based decision-making -Shared use of resources -Communication and joint knowledge management
	Information transparency (visibility)	Availability and accessibility of operational and inter-operational strategic information from and to all involved SC partners	Provision of information regarding: -Identity -Position -Status of objects in the SC
	Information sharing	Share relevant, accurate, complete and confidential ideas, plans and procedures in a timely manner with the involved SC partners	Information on: -Customer demand -Inventory -Shipping and transport logistics -Disruptions/current risks

Fig.6 Proactive and Reactive Supply Chain resilience measures (adopted and adapted from Biedermann 2018, pp. 184-185 and Pettit et al. 2010, p. 12)

Due to the correlation between the measures, focusing exclusively on either proactive or reactive measures is inappropriate, since, for example, proactive measures are essential to increase the capabilities of a company during the reactive stage (Ivanov 2018, pp. 47-50). Vice versa relying only on proactive measures without implementing flexibility into the SC is just as inefficient, because that approach would cost the company disproportionately much money and would affect efficiency, quality, and thus decrease competitive advantage (Sheffi and Rice 2005, Pettit et al. 2013, Tang 2006). Moreover, there does not seem to be a universal solution that would give companies precise instructions and concrete design plans on how to deal with disruptions for individual supply chains. Chopra and Sodhi (2004) have developed a well-directed approach that includes recommendations for actions based on different risk situations. However, due to the differences between companies (strategies, industries, customer needs, environmental influences etc.) and the dynamics of the markets, a generalisation does not seem possible. Consequently, many authors stretch the importance of the alignment of corporate strategies and risk mitigation approaches to reach individually customised solutions for companies (Tang 2006, Christopher and Peck 2004, Blackhurst et al. 2011). Lastly, it remains to be tested, whether the focus on lean management methods, high costs for redundancies and the dynamics of today's market environment have led companies to focus more on flexible risk management approaches (Sodhi and Tang 2012, p. 54).

This concludes the literature review. Numerous risk mitigation measures were found that will serve for a comparison during the evaluation later. The following chapter describes the context of this study: the global pandemic caused by the COVID-19 virus.

### **3 COVID-19 global pandemic: Introduction of the contextual frame of reference**

In this chapter, key points of the corona crisis 2020 are presented, that were deemed relevant for this study. This includes information about the origin and outbreak of the virus, the impacts of the outbreak and subsequent measures/restrictions that were implemented by the German government, examples for the severity of the crisis, and a clarification of the specifications of epidemic outbreaks in terms of SC risk management. At the end of this chapter, it is explained why the COVID-19 pandemic has created the need to conduct this research and some further assumptions are made regarding the possible outcomes of the empirical part of this study.

The coronavirus SARS-CoV-2 was discovered on the 7th of January 2020 and had its first appearance in the Chinese city of Wuhan. On 11 March 2020, the exponential increase in registered cases of the emerging virus forced the General Director, Dr. Tedros Adhanom Ghebreyesus, to officially declare the global pandemic outbreak. The scope of the pandemic in March 2020 covered 114 countries with a total of 118,000 reported cases (Euro - WHO 2020).

The German government has initiated several measures in response to the virus regarding, for example, mobility, economy, and borders (HSRM 2020). Therefore, cross-border traffic was temporarily restricted, and border controls were initiated. Also, entry restrictions for non-EU citizens and citizens of non-Schengen states to Germany by plane or ship were implemented. This includes a ban on entry for tourist purposes and seasonal workers. Additional restrictions included physical distancing and obligatory isolation/quarantine, for example, after entering Germany from abroad, infection with the virus or contact with infected persons. Furthermore, the debt brake was removed to secure sufficient resources to enhance the economy and to support the medical system. An additional 165 billion euros has been allocated to this purpose. Other measures include insolvency and tax regulations, the establishment of funds to amplify the equity base or take on the liabilities of enterprises, extension of working time and short-time allowance (HSRM 2020).

Partly despite, and partly because almost every country worldwide has chosen to take comparable countermeasures to prevent the virus from spreading further, the overall economic performance across all nations has decreased significantly. The main reason for the dramatic economic decline is an extensive disruption of global SC activities. Closed borders, worldwide trade and travel restrictions and enormous disruptions in sea and air freight meant that in Germany, for example, exports fell by 31 percent and imports by 21 percent in April compared with the same month last year (Tagesschau, 09/06/2020). In addition to the impact on the distribution of goods, the shutdown of production worsens the economic situation. Many companies had to temporarily stop production and close their plants, which, among others, led to supply shortages in various industries, such as healthcare or automotive (BBC 10/02/2020, WHO 03/03/2020). Another effect of the pandemic is a fluctuation in demand in almost all sectors. On the one hand, the demand for personal protective equipment (Unicef 04/05/2020), logistics services, e-commerce, IT tools (e.g. Zoom, Teamviewer, etc.), entertainment streaming and gaming has increased significantly. On the other hand, there are industries facing declining demand, such as aerospace, railway, cruise ships, tourism, oil and gas, traditional retail and manufacturing (The Conversation 20/03/2020).

The risk associated with the highly contagious virus can be demonstrated using the case of the German meat producer Tönnies Holding ApS & Co. KG. In June 2020, a mass outbreak of the virus occurred due to an infected employee at the company's site in Rheda-Wiedenbrück (Köppe and Koerth 2020). More than 2100 cases of COVID-19 infections are associated with the incident at the time of this study (Tagesschau, 23/07/2020). Due to the outbreak of the virus at its own site, the company was forced to close its plant and stop production (Tagesspiegel 11/07/2020). The company was criticised by society, politics and the press as a result of the incident and had to make multiple public statements especially concerning its security measures and undergo investigations by research institutions. According to an article published in the Spiegel, the employee responsible for the infection was previously at a church service where positive cases were later found. In such cases it is important to isolate people that potentially had contact with the virus. But when the employee informed his supervisor about the circumstances, the supervisor is said to have assessed the risk as low and the employee was allowed to continue working (Köppe and Koerth 2020). This misjudgement has consequently adversely affected the company and resulted in a lockdown of the entire region. Although the other safety measures required by law have been followed, the virus has been able to spread due to the special circumstances in meat production, which include cold air and constant air circulation (Köppe and Koerth 2020).

Furthermore, the severity of the impacts of the pandemic can be demonstrated by using the example of the German government's rescue package for the airline Lufthansa. The company has fallen into an existential emergency due to pandemic-related factors, such as travel restrictions, fear of infections among customers, and had to be secured by 9 billion euros from the government (Tagesschau, 25/05/2020). This case demonstrates the importance of the concept of viability discussed earlier. Furthermore, the question arises about what is making the global pandemic so difficult to manage.

Epidemic outbreaks are considered special cases of SC disruptions for three reasons (Ivanov 2020). First, because of the long-lasting existence and the unpredictable extent of the SC disturbance. Second, because of the simultaneous propagation of the disruption along the global SC and the spread of the virus in the population. Third, because of the simultaneous effects of the disorder on supply, demand and transport (Ivanov 2020). In addition to that, Ivanov and Das (2020) have identified the importance of the timing of closure and reopening of facilities for the recoverability of companies after a pandemic. This is associated with different lockdown periods in different countries and with the production shutdown and restart in different sectors, for example, in the automotive industry.

Comparing the case of a pandemic to a fire in a warehouse, these differences become clear. The fire, on the one hand, causes direct damage but is limited in time. The effects become quickly apparent in succession, for example, material damage, supply shortages, etc. On the other hand, an epidemic scales slowly and spreads further, increasing in severity and creating uncertainty about the duration of the adverse conditions. The fire is locally bounded to the warehouse, while the epidemic is geographically unlimited and therefore affects not only the initially impacted company (or country, region, etc.) but all SC members. While in the fire scenario the transport infrastructure and demand situation remain unchanged, in an epidemic, disturbances and fluctuations can be observed in all the areas ranging from supply and transport to production and demand.

In this context, the question arises as to whether the risk management methods recommended in the academic literature and normally used by companies in the event of disruptions to their SCs are also applied by companies during the corona epidemic and whether they are effective in mitigating the impacts of the crisis. Or, whether perhaps other more suitable methods that are not yet known in literature have emerged and are now being applied in practice (Ivanov and Das 2020).

Based on the gathered information regarding the COVID-19 pandemic some assumptions were made concerning the expected outcomes of the empirical research. Given the characteristics of the pandemic and the initiated measures of the governments, it is to be expected that companies that are less dependent on the flow of physical products and the presence and interaction of people will be in a better position during the pandemic, since they should have less difficulties working from home. The same potentially applies to companies that are already better equipped with IT and whose staff have better skills in this area, as they do not have to first acquire the necessary IT software and skills in order to continue their work and to adapt their processes. Further, it is expected that companies that meet these criteria will be better positioned to adapt to home office operations, will be less affected by supply shortages and will be able to take advantage of the benefits of IT, such as better visibility, etc. Finally, the role of the state in the context of the pandemic is expected to be more relevant than, for example, in the event of a fire in a warehouse or an earthquake in an industrial region. Besides, one example for state aid was already given above. This is assumed, because the entire population is affected and at risk. Furthermore, political measures sometimes weaken specific companies and must be compensated for by the state in order to secure the viability of the companies, as in the case of the airline Lufthansa. Eventually, the pandemic will have to be tackled across national boundaries in order to end it, as in times of globalisation the virus can easily spread beyond state borders.

These assumptions might be confirmed during the empirical part of this study, but before getting there, the next section first describes the methodology that was used for this study and explains why it was deemed appropriate.

#### **4 Methodology**

The objective of the study was to investigate how companies mitigate the risks and negative effects associated with the COVID-19 pandemic. This includes all measures that companies have taken since the publication of information about the first corona virus infection. In addition, preventive risk management measures that were already in place prior to the corona crisis were also considered. To achieve this, qualitative research in form of multiple-case studies of various companies was conducted.

Case studies are considered very effective when the research is aimed at answering the questions "how?" and "why?" (Yin 2014, p. 4). In addition, case studies investigate current events in their respective manifestations and present them in their respective environments. The cases are mainly based on expert interviews, whereby construct validity is ensured using additional sources such as company websites, annual reports and newspaper articles (Yin 2014, pp. 118-123). The possibility of triangulating the collected data also makes the case study approach more suitable for this thesis than simply conducting and analysing qualitative expert interviews. As this paper deals with a rather specific and little discussed subject, qualitative

research in combination with expert interviews is a well-established approach (Bogner 2005). Therefore, the methodology was considered to be appropriate for the purpose of this study.

This thesis follows a linear-analytic structure. First, the relevant literature was analysed in order to develop the theoretical framework. The next step was to find suitable candidates and collect empirical data by conducting expert interviews. The data collection period was approximately from the end of July to the end of August 2020. Subsequently, the cases were compiled based on the collected data. The cases are presented and described on an individual level and then analysed by means of a cross-case analysis (Yin 2014, pp. 164-168). Each case is presented as objectively as possible and comprises all the information gathered from the interviews, and secondary sources to ensure their internal validity (Yin 2013, pp. 45-47).

#### **4.1 Sampling**

The selection of suitable companies and interview partners was an important part of the work. The cases were selected based on purposive sampling methods. Therefore, primarily medium-sized to large companies were sought since they are more likely to have globally networked SCs, and as a result, are more likely to have experienced SC disruptions during the pandemic. Furthermore, the activities of the companies should also be connected with physical products (procurement, production, distribution), services involving the presence of people, and the transport of goods, so that a range of contact points with potential implications of the crisis could be established. In addition, the companies should preferably come from different industries in order to generate a high variance of potential mitigation approaches of the interviewed companies and thus not to limit the study to industry-specific phenomena. Locally, the sample was limited to German companies in order to reduce the scope of the thesis. This also ensured that all companies were operating in the same environment during the crisis and thus increases comparability for the cross-case analysis. Despite prior clarification of the study, communicating the purpose of the study and the provision of a non-disclosure agreement, the companies and respondents in this study were anonymised on request. An overview of the chosen companies is shown in Fig. 7.

The interviewees were chosen based on their work experience and position in the respective company. The focus during the search for candidates was set on positions like Supply Chain Managers, Risk Managers, Head of procurement/purchasing, Directors and CEO's. The potential experts were deemed appropriate if they have at least five years of work experience, have managed the corona crisis themselves, and have insights in the strategic decisions of the company regarding risk mitigation approaches for SCs. Therefore, the suitability of each expert was verified prior to the actual interviews to ensure the appropriateness of the sample. Interviewees who met these requirements were considered most suitable to answer the research question, as they have expertise in the field of SCM and since they have managed the crisis themselves are able to provide in-depth information for this study. An overview of the chosen interviewees is shown in Fig. 8.

Company	Industry	Primary products and services provided	Primary products procured	Number of employees/locations
A	Building - Automation	Devices, hardware and software that control, integrate, and connect building service system	Electronic components	1400 employees 50 locations
B	Maintenance of aircraft engines	Maintenance repair and overhaul of aircraft engines and industrial gas turbines	Engine parts	10.000 employees 15 locations
C	Online optician, e-commerce	Glasses, sunglasses, contact lenses	Frames, lenses, contact lenses	450 employees 31 locations
D	Electronics	Temperature and pressure sensors	Electronic components	4300 employees 8 locations

Fig. 7 Company Overview (adapted from Chen et al. 2019)

Company	Interviewee	Participants title	Data collection method	Specialisation
A	1	Logistics/shipping manager	Semi structured personal Interview, 50 minutes	Production and Logistics
B	2	Head of Purchasing	Semi structured interview by phone, 60 minutes	Supply Chain Management, Aerospace
C	3	CEO and Founder	Semi structured interview by phone, 40 minutes	Strategic Management, e-commerce
D	4	Vice President Logistics	Semi structured interview by phone, 30 minutes, written information per e-mail	Supply Chain Management

Fig. 8 Interviewee Overview (adapted from Chen et al. 2019)

## 4.2 Data collection

Semi-structured interviews were chosen as the method of data collection. The interviews lasted 30-60 minutes and provided deeper insights into the companies investigated. Due to the tight time schedule of the respondents it was extremely difficult to find a date for an interview, so some interviews were conducted by telephone. Respondents were asked for permission to record the interview so that all information could be reviewed at a later stage, especially during the analysis. Based on the evaluated literature, the research question and the chosen method of analysis, an interview protocol was developed (appendix). Most questions were asked as open-ended questions in order to avoid or minimize bias (Yin 2013, pp. 110-113). The interview protocol started with questions on general information about the respondent, the company and its SC. It then contained questions about how the company was disrupted by the pandemic and what its response to each disruption looked like. Further questions were asked about the measures that the company normally applies to SC disruptions, but which were not practicable due to the specific circumstances of COVID-19. Finally, the interview protocol included questions about the importance of risk management in the company and the respondent's opinion about the role of the state during pandemics. The interviews represent the most



important data sources for this study, followed by company websites, company documents and newspaper articles. Wherever possible, these data were verified using triangulation methods.

Without personal connections to potential companies and interview partners, establishing contact proved to be extremely difficult. During this study four interviews could be conducted. Due to the slow response from potential interview partners it took up to 4-6 weeks to make an appointment and some other potential interviewees were not able to fulfil their initial commitments in the end, so further interviews could not be conducted. The overall low response from potential participants might also be related to the ongoing crisis, as it is assumed that many managers currently have fewer resources available for an interview. This was also observed, for example, in form of tight schedules and little time for interviews, among participants who agreed to take part in the study. These circumstances have to some extent limited the available data for this study and thus the number of cases. Nevertheless, as this study is intended to examine and describe how companies have managed the crisis, four cases should be sufficient to provide insights into the circumstances in the investigated industries.

### **4.3 Data analysis**

Since the aim of this work is exploratory and descriptive in nature, the development of a case description was chosen as a strategy for analysis (Yin 2014, pp. 139-140). For this purpose, the data were coded, and clusters were formed to better assign the data to the individual points of analysis. The different areas of disruption, i.e. supply, transport, production and demand, were analysed for each individual case and the measures taken by each company to deal with the disruption in question were identified. The literature review has provided an in-depth overview of traditional risk mitigation measures. This overview was used to compare the empirical data with the theory in order to determine whether new risk mitigation measures have been discovered and whether the traditional methods have been applied by companies during the crisis.

This concludes the methodology part. The following sections comprise the analysis and description of the single cases as well as the cross-case analysis.

## **5 Single case descriptions**

The single case descriptions are the result of the analysis of the collected data. The cases are offering insights and details about the companies that were interviewed for this study and their experiences during the crisis. Each case starts with a general description and information about the company regarding the industry, core competencies and activities, its supply network (including suppliers, production facilities, customers and transportation modes), and other background information. Then, all disruptions and risks that the company had to deal with during the crisis are presented, followed by the measures the company has initiated to deal with them. The goal in this part was to show which risk management methods the company has used during the crisis and thus to contribute to the achievement of the objectives of this research.

### **5.1 Company A**

The company, founded in Germany over 90 years ago, is operating in the field of building automation and is one of the leading competitors in the industry. The company has about 1400 employees and 50 locations worldwide. The company's competencies and business activities

include the development, production, implementation and maintenance of devices, hardware and software that serve to integrate and connect building services systems such as heating, ventilation, air conditioning and fire protection. The supplier network comprises several thousand partners distributed worldwide that are located in East Asia, the USA, the Far East but also in Europe and Germany. Due to the characteristics of the industry, the company's procurement is cyclical. This means that during peak periods one is tied to high delivery times across the entire industry. The company therefore maintains high stocks even in business as usual situations in order to maintain its ability to deliver. The own production happens exclusively in Germany at two locations with a high production depth, i.e. a very large share of the components is produced in the company itself. Consequently, interviewee 1 stressed the resulting independence from suppliers and the increased control as potential disruptive factors are reduced. Nevertheless, there are dependencies between the two locations because some products are produced exclusively at one of the two locations and are then distributed internally. Most of the products manufactured are sold internally to the company's own sites. These sites, in turn, offer the implementation of the products in buildings. The largest customers are therefore clients of construction projects who pay for the implementation service. Such projects often extend over several years.

According to interviewee 1, disturbances caused by corona were, for example, extended delivery times by several weeks on the supply side, due to the lockdowns in China. However, complete delivery failures have never occurred. A problem was the high level of uncertainty about suppliers' ability to deliver and the resulting uncertainty about the company's own ability to deliver to customers. This circumstance created a lack of transparency along the SC. Transportation disturbances were also experienced. For example, one specific product group was affected because the delivery from northern Italy was impossible due to the lockdown there.

The own production was affected in only 3-5% of the offered products. Such products were impacted by delivery delays for up to four weeks and in one case there was only a single source available for a product. The rest of the production remained relatively stable although the capacity utilisation was slightly lower than usual. According to respondent 1, production capacity is never fully utilised, so this situation was no serious problem for the company. This is also due to the nature of the industry, the long-term character of the construction projects and the demand characteristics.

A real problem and risk was the fluctuation in demand. Depending on the sector, demand has increased in some cases, for example, orders for maintenance work in hospitals have increased as they had to prepare their facilities for a large number of patients and their treatment. But on the other side, demand has decreased, especially for construction projects abroad, as most of them have come to a standstill during the crisis. But also in Germany, where, according to interviewee 1, construction projects are usually not interrupted so quickly, demand has decreased especially for customers like hotels, restaurants and similar facilities. These customer groups have in most cases cancelled their orders since they were severely hit by the crisis and could not afford any additional investments as their financial situation was dramatic, for example, with up to 80% loss of sales in the gastronomy sector. Therefore, one of the biggest concerns for the company was the vulnerable financial situation in case of order losses or own production shutdowns due to infections.

In order to secure liquidity, financing measures have been introduced, which include state aid, short time working compensation and the postponement of invoices. Furthermore, the

company introduced a broad range of protective measures to ensure the health of its employees thus preventing potential production shutdowns as a result of infections. Such measures include, for example, providing protective gear (Respiratory masks, gloves, splash protectors, etc.), communicating health guidelines (safety distance, hygiene, etc.) and introducing home office. Employees were also allowed to take turns looking after their children at work in designated rooms to ease the private situation resulting from closed kindergartens and schools.

Assumptions and forecasts regarding the supply situation were made and inventories increased accordingly. A multiple sourcing approach is pursued for almost all products, whereby some products are so specialised that a single source must be used. Hence extra high inventories are used for single-sourced product groups to prevent supply shortages. Multiple sourcing enabled the company, for example, in the case of transportation problems with some products from northern Italy, to have flexible access to other suppliers. These products were then sourced from German suppliers instead. In addition, due to the flexible product design of many articles, other product components can also be used without impairing the functionality of the final product. This has helped the company in the case of a product which only had a single source available, because the company was able to use other components to ensure the functionality. Finally, due to the high inventories, the firm never really struggled with supply shortages. Still, the company has tracked emerging supply implications for various products caused by Corona (such as delivery delays), communicated them internally and to their partners, and made them transparent in IT systems. This way, the company was able to monitor which product groups are affected by the crisis and could share this information with the involved parties.

Regarding the demand situation, the company was not able to take measures to mitigate the effects of the crisis. Since many customers were facing high uncertainty about their financial status and thus their survivability, it is assumed that they could not afford any extra investments in building automation. The only way for company A was to acquire other customers. Fortunately, hospitals and some other customer segments had increased their orders. This helped the company to eventually balance its sales and secure a stable financial status.

The managers were also supported in form of information (for example, about short-time work), contacts and communication guidelines. According to the interviewee, there were no concrete emergency plans in advance. Instead, the company relies on case-specific real time responses and communicates the developed plans to all employees. Above all, it was stressed that corporate leadership and communication were essential for surviving the crisis. Since top management provided daily Corona status reports to its employees, communicated all initiated measures and illustrated worst-case scenarios, the workforce was united and motivated to support the company with full commitment, which meant that decisions could be made faster, there was less need for discussion with the employees, and all pursued a common goal: to ensure the survival of the company.

In conclusion, the interviewee stated that the company has successfully mitigated the impacts of Corona, as the order situation was balanced among the different customer segments, production could always be maintained by protecting the employees, and delays in delivery had only a minimal impact due to high inventories, flexible supply base and production design, and second sources.

## 5.2 Company B

Company B is a mechanical engineering company with 15 locations worldwide, spread across North America, Europe and Asia, and approximately 10,000 employees. The Munich-based company was founded in 1934. In Germany, the company is a leader in the aircraft engine manufacturing and maintenance business, offering products such as high-pressure compressors, low-pressure turbines, turbine centre frames, and repair and manufacturing processes. The company develops, manufactures, sells and supports aircraft engines in all thrust and power categories, as well as stationary industrial gas turbines used, for example, in oil production. The corporate business covers the entire life cycle of an engine program, from the development, design, testing and production of new civil and military engines and spare parts to maintenance services for civil and military engines. The company's activities comprise two segments: the civil and military engine business (called original equipment manufacturer business: OEM) and the civil maintenance, repair and overhaul business (called MRO business). The MRO segment accounts for approximately 58% of revenues and represents the major source of income for the enterprise. The company has various subsidiaries and associated firms, which allow the company to be present worldwide. Interviewee 2 works in the MRO segment and is Head of Strategic Purchasing at a location near Berlin, where approximately 900 people are employed. Further locations are, for example, in Vancouver (Canada), Zhuhai (China) and Hanover (Germany). In this way, the company aims to create a regional footprint, which means that the respective locations primarily supply the corresponding markets. Given the high importance of the MRO segment for the company as a whole and the similarities between all MRO locations, it is appropriate to consider this location as a representative example for the company's business. The special feature of the Berlin location is its high product diversification, i.e. industrial gas turbines, helicopter engines and aerospace turbines are maintained there. Company B's customers and partners include companies in the military sector and the oil industry (for industry gas turbines) as well as airlines, OEMs of engine parts and engine manufacturers (for aerospace engines). The overall customer structure is very international and geographically distributed, which is why the company has also opened smaller workshops worldwide, for example, in Thailand, South and North America, to provide local support. The suppliers are also international and located in New Zealand, Thailand, Singapore and Eastern Europe but mainly in the USA, Mexico and Canada. The company is in some cases very dependent on its suppliers, as high standards prevail in the aviation industry and therefore some parts, especially in the OEM sector, only have single sources. The MRO service that the company provides has two different forms, one which is comparable to a car workshop (local) and one that sends a repair team to the customers site (mobile). In the local version the company receives the engines, checks and cleans them, disassembles them, repairs or exchanges parts depending on the job, re-assembles them and sends them back to the customer. The mobile version of the service includes the transportation of the mobile repair team, i.e. people, which is important to note as we get into the disruption analysis.

According to interviewee 2, the company was caught unprepared by the developments of the crisis. The company had originally set very high market expectations and growth forecasts for 2020, since the company has had annual growth rates of around 5-10% in the past. This growth ended abruptly with the outbreak of the Corona crisis at the beginning of 2020. The company had seen order declines of up to 80% in the aviation sector and share value losses of up to 65%. Meanwhile, demand for industrial gas turbine maintenance has remained stable as capacity

utilisation for company B was at 90-100% in this segment. However, the major threat for Company B is the development of the aviation sector.

Many suppliers in the aviation sector have laid off 20-30% of their workforce in June and in some cases closed plants, scaled down product lines and reduced capacity from 100-120% utilisation before the crisis to 50-60% in August 2020. The company did not expect these developments on the supply side, as the consequences of the crisis for its suppliers were not yet noticeable in March and April 2020 and only became apparent months later. As a result, the company now expects fatal developments for the 4th quarter 2020 on the side of suppliers and customers alike. For example, bankruptcies, company takeovers and fusions are anticipated. In addition, there were COVID-19 infections on the supplier side, which is why some suppliers had to close their production temporarily, thus reducing output, which led to higher turnaround times at Company B.

Similar developments are also expected on the demand side. The capacity utilisation of airlines has fallen dramatically as a result of political measures, continuing uncertainty and restraint among the people, as well as many travel warnings due to rising COVID-19 case numbers across Europe during the summer months. As a result, orders for maintenance work have also fallen drastically. At the time of this study there is great uncertainty about whether the customers of Company B will survive the crisis and how the situation will look like for the survivors. Therefore, the order volume in the coming months reaching far into 2021 is expected to be far below the usual level. Respondent 2 expressed concern that even after the end of the crisis, the number of business trips by air will remain up to 30% below the level of 2019 as enterprises may stick to the virtual version of business meetings and keep on reducing personal contact in the future as well.

On the operational side, the company itself of course faced risks regarding the infection of the employees, the restructuring of the operational business due to the pandemic, and the utilisation of the production capacity.

Regarding the transport of goods, the company did not have major disturbances except for some delivery delays of 2-4 days. However, it became impossible to send the mobile repair teams to the customers, as the transport of people was still prohibited by the political authorities during March and April. As a result, while the restrictions continued, this part of the service was completely cancelled.

In order to mitigate any potential transport risks, the company maintains close cooperation with its logistics service providers and, as already mentioned, has managed to get through the crisis successfully in this respect. However, the company was not able to do anything about the government's restrictions on the movement of persons and therefore had to wait until these restrictions were lifted.

Regarding its suppliers, company B first categorised them in order to identify which suppliers are affected and with what degree of severity. In this way the company tried to create transparency about the supply situation. Close contact with the suppliers was maintained, communication happened in form of virtual meetings, and information was passed on among the SC partners. In this way, the company tried to derive measures in terms of inventory management, i.e. whether, for example, increased stocks need to be built, whether top management needs to be involved, etc. However, according to respondent 2, in some situations the outcome was that company B was unable to take any measures to deal with the situation.

This is the case, for example, when as mentioned above, an OEM only certified one single source. Other suppliers can hardly be generated in this industry and thus limit the possibilities for companies that are dependent on the OEMs, like in this case, company B. Besides that, in some cases the volume for some products did not justify building a second source. Ultimately, according to interviewee 2, the company's supply situation was not the main problem during the crisis in the first place, as the adjusted supply level, for example, due to capacity reductions by suppliers, was still sufficient to satisfy the lowered demand caused by the crisis.

In order to protect its own production, company B had to define accurate hygiene measures and work concepts. Therefore, the company was closing its site in Berlin for several weeks. During this time an emergency team was formed which handled the urgent operations until the re-opening. It took the company 2 weeks to reconfigure operations and implement the measures for protection as well as to enable home office operations for administrative staff. Protective measures include safety distance, provision of face masks and hand disinfectant, the formation of A and B teams that alternate between home office and presence operation, and the avoidance of any visits and business trips. Consequently, the company successfully protected its employees and was not forced to shut down its site due to infections. Nevertheless, the company is on short-time work, and will most likely need until 2021 and longer to change this situation. Naturally, the company's output and service levels have fallen to a lower level during the crisis. The high amount of work in progress and backlog of orders has provided the company with a relatively stable production capacity utilisation until June, but this is now becoming increasingly difficult to maintain since the existing orders are mostly completed and only a limited number of new orders are being placed. Still, respondent 2 indicates that due to Company B's diversified product portfolio, the situation is better than for other providers of aircraft maintenance services that are focusing exclusively on aircraft engines.

The demand situation represents the main threat and disruption for company B. In order to evaluate the demand situation, first, a similar categorisation as for the suppliers was carried out. Particular focus was set on identifying which customers are still in a position to pay and which ones are especially threatened by the crisis, in order to prioritise orders and decide whether the orders should be processed at all. In addition, orders from less affected customer segments could be processed, for example, orders for industrial gas turbines. The company is also benefiting from high margins in turbine maintenance, which is stabilising the financial situation to some extent. Finally, the company is trying to acquire new customers, which is extremely difficult as such customers are very scarce on the market and all competitors are trying to acquire these customers. The demand situation can hardly be influenced by company B. Airlines have difficulties to generate demand for their flights and are in a fragile financial situation. The industry is especially impacted by political restrictions and the fears that keep the customers from traveling. The same is true for the tourism industry. As both industries correlate with each other, the vulnerable situation of the associated companies is unlikely to change soon. In this context, respondent 2 has stretched the importance of financial buffers within the company and safety net mechanisms of the German government, i.e. financial aid, short time work, etc.

Although company B has managed its SC successfully in terms of securing supply, ensuring the continuity of production, and mitigating transport risks, the situation is still worse than in most other industry sectors, because of the severe disruptions in demand.

### 5.3 Company C

The next case presents a relatively young company that is active in the e-commerce industry for eyeglasses, sunglasses and contact lenses. As “online optician” and its novel way of selling eyeglasses over the Internet, the company became a pioneer in the eyewear industry, with innovative services such as online vision tests and virtual eyeglass fittings. The company employs about 450 people, has 31 locations in Germany and is active throughout Europe. What has started as an online shop for eyewear in 2007, is today a multichannel company with over 500 partners (mainly opticians) and its own offline stores that also offer services such as eyesight tests or eyeglasses adjustments. In 2020 alone, the company has opened 12 new stores despite the COVID-19 crisis, demonstrating the company's strong growth and commitment to continued expansion. Offering above 10.000 glasses and sunglasses the company provides the largest immediately available assortment of brand eyewear in Europe. The main products that the company procures are frames, lenses and contact lenses. These products are primarily sourced from European suppliers, with second tier suppliers largely coming from China, Korea or Japan. A large proportion of the components required to produce eyeglasses are coming from China and northern Italy, both regions that were particularly severely affected by the corona crisis. The production of the company itself is located in Berlin. Here, the company assembles the frames and lenses and customises the lenses for the customers. The Berlin site is also the company's largest logistics centre, while additional centres are located in Stockholm and a smaller one in Norway. The delivery of the finished glasses to the approximately 5 million private customers is carried out by logistics service providers. A difference to the previous cases is that Company C is not active in business-to-business, but in business-to-customer operations.

The company already experienced the first effects of the coming crisis in January 2020, when Chinese suppliers were no longer able to deliver some products. This was accompanied by a decline in demand. Interviewee 3 assumed that customers had other important things on their minds, such as childcare and basic needs, and therefore could not think about investing in new glasses. Where glasses had to suffer a temporary decline in demand, contact lenses have boomed. Interviewee 3 even said that "contact lenses were the toilet paper of ophthalmic optics", referring to the rush by German citizens towards the supermarkets' toilet paper stocks to prepare for the potential lockdown.

The infection of an employee, especially at logistics and production sites, was also considered a major risk. According to interviewee 3, none of the responsible authorities were able to give any concrete statements on how the company should be set up in terms of hygiene and protection measures in order to avoid the obligatory closure in case of infection. Other risks included financial security and transport capacities. While the financial situation of the company is relatively robust the company still had to suffer declining sales since all offline stores were closed and after the re-opening the demand has only increased slowly. However, the e-commerce sales have increased which benefitted the company overall.

Regarding the transport of goods, the company was facing a decline in available capacities. This is because most products are transported daily in passenger planes due to their compactness and low weight. Since the demand for air traffic has decreased significantly, the available transport capacity has also decreased. In addition, when production resumed in China, the products had to be shipped by air freight because the sea freight transport capacities were not available. This was far more expensive and was therefore an important financial issue for the company. Other transportation problems arose, for example, in the supply of northern Italy, and

some regions in France and Spain. Deliveries there were not possible at all as logistics service providers have temporarily stopped their operations. The lockdown also proved to be a challenge for Company C's business model. After the glasses had been ordered online and delivered, customers in Austria, for example, could not leave their houses to hand in returns at the post office, because of the political restrictions.

As a first step to manage the crisis, the company has calculated various scenarios based on assumptions regarding sales losses, operating costs, duration of the crisis, and liquidity, and found that the company is well secured in this respect. Nevertheless, the company introduced short-time work, postponed planned store openings, shifted capacities, and reduced marketing activities, as the development of the situation and thus the effects on the company could not be foreseen. In response to the supply insecurity that was recognized early on, the company acted quickly and, with an investment of 10 million euros, virtually doubled its stocks, which meant that it never experienced supply bottlenecks during the crisis. This has also helped the company to protect itself against temporary transport difficulties, as further deliveries were not urgently needed. The next step included measures to be able to continue operations.

Therefore, the company enabled home office operations for headquarters and customer service. The interviewee mentioned that the company had already been working with cloud-based software for two years before the crisis. Consequently, the reconfiguration of the operations, i.e. enabling home office, operating via cloud-based systems, etc., had been completed quickly. In addition to the resulting ability to maintain operations, this measure also served to protect employees from infections by ensuring social distancing. Moreover, security measures were taken to further prevent possible infections and resulting contagions among employees. They include providing information about protective measures, reminding employees to stay at home if they suspect infection, and introducing rules for health protection such as wearing protective gear like face masks, etc. The company has also introduced a separation of shifts in production and warehouse to minimize the risk of a facility lockdown and so that in case of an infection only the affected shift would be quarantined. This would enable the company to continue operating at least at a capacity of fifty percent. Furthermore, the company adjusted processes to minimize intersections between divisions and thus reduce personal contact inside the firm. The company also closed all offline stores and introduced protective measures when they re-opened, i.e. providing hand sanitiser, allowing only a limited number of people inside the store, ensuring safety distance and wearing face masks. Business trips abroad were cancelled, and all business meetings were conducted online using team meeting software. Finally, since August, all returning employees who want to resume their work after a stay abroad are first tested for the virus. These measures were extremely important for company C as it has only one production site with no alternative possibilities, so that in case of closure the whole production would stop.

According to interviewee 3, demand has regulated itself. Indeed, the sales of the offline stores have collapsed, but were absorbed by the increase in online sales, so that the company has remained more or less at the same level as before the outbreak of the pandemic. Also, the stores were only closed temporarily and could continue their operations after the shutdown. Furthermore, according to German law, opticians are system relevant and therefore company C's stores would not have had to be closed at all. However, in order to protect its employees, the company decided to close them for several weeks. Ultimately, the sales declines in the French, Spanish and Italian markets caused by transport difficulties were not significant, as they



were only temporary, and the markets do not account for a critical share of sales. So, they could be compensated by financial buffers of company C. In addition, the logistics service providers soon offered a solution that allowed customers to have their returns picked up from home, making the process of online shopping easier during the crisis. In this regard, respondent 3 has stretched the importance of process adaptability, for example, to enable different sales channels for reaching one's customers.

Company C has successfully overcome the crisis due to a quick reaction to potential supply difficulties, preventive measures to protect employees and because difficulties in transport were only marginal. In particular, the e-commerce business model has proven its advantages, which were even more essential during the pandemic. The industry itself was also less affected than others due to the basic needs of many customers to have access to eyewear, and therefore demand remained stable automatically without the need for major intervention measures by Company C.

#### **5.4 Company D**

The company comes from the electronics industry and belongs to a global player that employs a total of 107,000 people worldwide, is active in Asia, Europe, North and South America, and has more than 200 factories, R&D sites, and sales offices in more than 30 countries. The organisation was founded in 1935 in Japan and offers a wide variety of products such as passive components, sensor-, magnetic-, and energy application products, and others. For this study, an interview partner was acquired who works in the Temperature and Pressure Sensors business unit of the organisation, which is based in Berlin and employs around 4300 people at eight locations in Japan, China, Indonesia, USA, and Europe. The company is specialised in the development, production, and marketing of temperature and pressure sensors. Main customers are almost all major OEMs in the automotive industry where the sensors are used in heating, air conditioning, engine management and e-mobility. Further customers and application areas of the sensors are manufacturers of household appliances (refrigerators, washing machines, water boilers, heaters, etc.) and companies in medical technology (respirators, anaesthesia and patient monitoring). The supply network comprises partners from Asia, the USA and Europe. Procured products include, for example, electronic components, ceramics, plastic granules, and adhesives.

The company was threatened by supply risk as most of the production of its suppliers is located in China, where lockdowns have forced the companies to shut down their production for several weeks. Suppliers from the USA, Spain and Italy also had difficulties to deliver when the virus reached these countries.

The availability and costs of transportation were also a problem for the company. The closure of the ports due to the pandemic has created a backlog of orders for sea and air freight providers. In addition, there was an increase in demand for transportation services after the sequential reopening of production worldwide, which led to exploding prices in the freight transportation industry. According to interviewee 4, prices for air freight were three to four times higher than before the lockdowns. As a result, there was primarily a financial hurdle, since the freight transports as such were available again but expensive.

Alongside the supply and transportation issues, the company was particularly affected by demand-side disruptions. The reason for this is that most of the customers are mainly from the

automotive industry, which was severely impacted by the crisis and has therefore also negatively affected its partners, such as company D. Many OEMs in the automotive industry have shut down their plants for several weeks because the supply situation was heavily disrupted. Major customers of company D cancelled orders at last minute, postponed the delivery of the ordered goods or refused to accept the goods without prior notice. Due to the uncertain demand situation, the company had difficulties in planning its own production, as it did not know how many products it could sell and deliver to its customers.

The production of the company was at risk due to the possibility of an infection and the resulting shutdown. Furthermore, the company was facing problems regarding the available space at its own warehouse, since the goods that the company has ordered before the crisis were already on their way and thus continued to arrive at the warehouse. On the other side, finished products were not allowed to be shipped to the customers which significantly increased the inventory levels at company D. Stocks of some products had reached levels that would have lasted up to 7 months of constant production.

For emergencies, the company has predefined contingency plans, guidelines, and protocols that must be strictly followed. In this case, the company started to assess the inventory situation and calculated how long inventories would last before they run out. Therefore, the company clustered the products by criticality, investigated alternative sources of supply, and, if possible, used second sources. However, the supplier situation is not so simple. Since OEMs in the automotive industry only approve new second-tier suppliers once a year and the process to obtain new approvals for suppliers is subject to enormous bureaucratic and time-consuming efforts, such changes are not easily made. In addition, the suppliers must be audited first and then qualified enough to produce specific products, which is often an obstacle. Therefore, second sources and flexible alternatives are not always available or easy to generate because resources and time for the process involved are limited, especially during times of crisis. Despite this, because the company had certain prescribed safety stocks and transport services were available again after the lockdown period (although these became very expensive and posed a financial burden), supply was largely intact. In this regard, the interviewee also stretched the importance of communication with suppliers especially during a crisis and said that the suppliers themselves were very committed to being able to deliver again as soon as possible which reduced the overall duration of the supply side impact and thus increased recoverability of the SC.

As a result, the production of company D was not interrupted by any supply shortages, and in the case of the lockdown in China, the company was able to shift capacity to Indonesia. However, the demand situation had serious negative impacts on the company and remains uncertain. In March and April in particular, the company was facing a decline in sales, increased inventories, uncertainty about demand, and was operating at low production capacity utilisation. The company initially allowed its customers to postpone certain orders, but soon had to insist that the goods were delivered and paid for. The problem in the automotive industry is that OEMs have much more power in determining the details of contracts etc., so Company D was at a disadvantage and had little room for manoeuvre. This also lowered the credibility of the OEMs and the trust of company D to its customers. Due to the unreliable information from its customers, the company could not predict potential demand and could not plan production properly. According to respondent 4, the normal instruments used by the company in such cases could not be applied. For example, the respondent indicated that a demand forecast for one

month was useless for company D, as delivery times for sea freight alone were 8 weeks, making long-term planning impossible. These circumstances have lasted for several weeks. The slight increase in demand from medical technology companies and the relatively stable demand in the household sector provided the company with some room to breathe after all. The re-launch of production by car manufacturers after the lockdown has also stabilised the situation at least a little. Additionally, short-time work has helped to improve the financial situation of the company during the crisis and still does as production remains at low capacity. In order to create more space in the warehouse, the company has built tents to cover part of the stock until the situation would improve. The company has also recognised the importance of protective measures to prevent production shutdowns due to infected workers and has therefore introduced hygiene measures including the wearing of face masks, safety distance, provision of hand disinfectants, separation of break times and others such as home office for administrative staff etc. In conclusion it is important to note that the fact that Company D has experienced few supply difficulties is also linked to the decrease in demand, as less raw material was needed for production and the safety stocks could more easily compensate for delivery delays.

According to interviewee 4, the company is still in the middle of the crisis, as the future remains uncertain, and stability can only be established slowly. In the short term, the continuity of company D depends to a large extent on the development of its customers in the automotive industry, as new customers cannot be generated as quickly as it is often recommended in theory, explains interviewee 4.

## 6 Cross case analysis

In this section, the single case analyses are presented together and compared with each other. This is intended to analyse and visualise possible cross-case connections of the findings. In addition, this section will evaluate the data regarding pandemic-specific factors. In order to give an overview of all cases Fig. 9 presents the key points of each case.

Company	Supply	Transport	Production	Demand
A	- no production standstill as a consequence of supply shortages -lack of transparency and high uncertainty	-no severe impacts on operations due to transport difficulties -delivery delays of several weeks -in some cases, supply issues because deliveries were not available	-mostly intact except for 3-5% of the products -marginal impacts -short time work, reduced capacity -no shutdown as a result of infections	-demand decrease in affected customer segments -demand increase in certain other customer segments (e.g. hospitals) -overall stable

Company	Supply	Transport	Production	Demand
B	<ul style="list-style-type: none"> <li>- no production standstill as a consequence of supply shortages</li> <li>-increased risk as suppliers are likely to become bankrupt, etc.</li> <li>-high uncertainty of the supply situation in the future</li> <li>-supply was sufficient for the adapted production level</li> </ul>	<ul style="list-style-type: none"> <li>-impacts on mobile service during March and April</li> <li>- delivery delays of several weeks</li> </ul>	<ul style="list-style-type: none"> <li>-production stable until June due to backlog and existing orders</li> <li>-increasingly difficult to maintain capacity utilisation at a constant level</li> <li>-short time work, reduced capacity</li> <li>-no shutdown as a result of infections</li> </ul>	<ul style="list-style-type: none"> <li>-severe disruptions on demand side</li> <li>-no mitigation measures available due to dependency on aerospace industry</li> <li>-dependency on political measures</li> <li>-high uncertainty now and in the future</li> </ul>
C	<ul style="list-style-type: none"> <li>- no production standstill as a consequence of supply shortages</li> </ul>	<ul style="list-style-type: none"> <li>-minor impacts on operations in a few markets</li> <li>-increased transportation costs</li> <li>-lowered transportation capacity available</li> </ul>	<ul style="list-style-type: none"> <li>-production was intact</li> <li>- short time work</li> <li>-no shutdown as a result of infections</li> </ul>	<ul style="list-style-type: none"> <li>-partly decreased demand at the beginning of the crisis</li> <li>-decreased demand in offline stores during the lockdown</li> <li>-overall stable demand due to increased e-commerce sales, and need for eyewear among the customers</li> </ul>
D	<ul style="list-style-type: none"> <li>- no production standstill as a consequence of supply shortages</li> <li>-supply was sufficient for the adapted production level</li> </ul>	<ul style="list-style-type: none"> <li>-no severe impacts on operations due to transport difficulties</li> <li>-increased transportation costs</li> <li>-lowered transportation capacities available</li> <li>-represents more of a financial issue</li> </ul>	<ul style="list-style-type: none"> <li>-uncertainty of demand made production planning impossible</li> <li>-short time work, reduced capacity</li> <li>-space issues in the warehouse</li> <li>-no shutdown as a result of infections</li> </ul>	<ul style="list-style-type: none"> <li>-decreased demand in major customer segments (automotive)</li> <li>-slightly increased demands from medical technology companies</li> <li>-overall unstable demand and high risk due to the dependence on the automotive sector</li> </ul>

Fig. 9: Overview of the single cases

The overview shows that the companies have mitigated the disruptions on supply side very well. No company was facing production standstills as a result of supply shortages during the crisis. Transportation difficulties were also well managed and had only marginal impacts on the SC, except for some cases like company B, that was not able to provide the mobile service for several weeks, and company C that was temporarily disabled to reach the customers in certain regions. However, in the production, more difficulties have occurred, such as the inability to plan or issues regarding the utilisation of capacity. This is mainly caused by demand fluctuations and incomplete information. In terms of protecting the production against an outbreak of the virus each company succeeded. The demand side disruptions are presenting the major problem across the cases. The companies experienced more difficulties in managing their demand than in managing the other disruption areas. Especially industry specific disruptions are to be noted. What mitigation measures the companies applied in detail is discussed in the next section.

### 6.1 Analysis of empirically identified risk mitigation measures

The risk mitigation measures identified during this study are summarized in Fig. 10. They include measures for mitigating impacts and risks in the areas supply and transport, production, demand, information, finances, response and general crisis management. While many different risk mitigation measures were identified during this study, there were no non-traditional measures identified during the comparison of empirical and theoretical data.

According to the interviewees, risk management has a high significance in each company across all four case studies, i.e. in each case risk management methods were already established before COVID-19. This is visualised in Fig. 10, as each company has applied a great variety of measures to mitigate the impacts of the crisis, and often the same measures were applied across companies. In this respect, only two out of four companies indicated that they had used predefined contingency plans during the Corona pandemic. Note that both companies belong to the larger companies, i.e. B and D, while the rather small companies A and C relied on more reactive and flexible approaches. Some basic measures that seem to be especially important in pandemic situations were identical in all case studies. They include financing measures to secure liquidity, receiving state aid, in particular the application of short-time work, and safety and hygiene measures to protect employees and customers from infection.

Area	Empirical examples of mitigation measures	Company			
		A	B	C	D
Supply/ Transport	Multiple sourcing (proactive)	X	X	X	X
	Multiple Sourcing (reactive)	X		X	
	Safety stocks	X	X	X	X
	Supplier Management	X	X	X	X
	Flexible transportation routes and modes			X	X
	Flexible Product design (flexible components, multiple use, etc.)	X			X
	Forecasting	X		X	X
	Inventory Management	X	X	X	X

Area	Empirical examples of mitigation measures	Company			
		A	B	C	D
<b>Production/ Operations</b>	Hygiene measures	X	X	X	X
	Flexible/adaptable operations (home office, process reconfiguration, etc.)	X	X	X	X
	Order Management (Prioritisation, postponement, etc.)	X	X	X	X
	Capacity management (reallocation of production, redundant capacity, adapting capacity to demand, etc.)	X	X	X	X
	Flexible facilities				X
<b>Demand</b>	Dispersion of markets	X	X	X	X
	Diversified product/ customer portfolio	X	X		X
	Flexible distribution (multiple channels)			X	
	Customer Management	X	X	X	X
<b>Information Management</b>	Communication	X	X	X	X
	Collaboration	X	X	X	X
	Information transparency	X	X	X	
	Information sharing	X	X	X	X
	Culture	X	X	X	X
	Real time monitoring and IT infrastructure	X	X	X	X
<b>Finances</b>	Financial measures	X	X	X	X
	Price margins		X		
	Financial buffers		X	X	X
	Government support	X	X	X	X
<b>Response</b>	Predefined contingency plans		X		X
	Management support	X	X	X	X

Fig. 10: Overview of empirically identified risk mitigation measures.

### 6.1.1 General crisis management

As discussed in the literature review, a pandemic raises the need to consider the viability of companies. In this context, some fundamental measures were identified in each case that aim to secure the continuity of the company and protect the employees. Starting with financial measures to secure liquidity and prevent insolvency. The details of individual financing measures were not disclosed, but the statements of each interviewee were generally associated with taking out loans, postponing bills and reducing costs. In addition, all respondents indicated that financial buffers offer a higher degree of security and help the company to stay calm and

make well-considered decisions. However, not every company has the possibility to hold correspondingly high financial reserves and the justification of such reserves is difficult, as the emergency case may never occur. State support has of course also been mentioned in this respect but should be viewed separately. The support provided to companies by the German government was named across all case studies as a means of crisis management during the pandemic. Some interviewees even compared their own situation to partners in the USA or southern Europe where governmental safety mechanisms like the short time work system in Germany are not available, so in many cases these partners had to lay-off thousands of employees. Therefore, each respondent stretched the importance of governmental support in order to prevent insolvencies and unemployment. None of the companies has commented on what the financial situation would be like if the state aid did not exist. But in conclusion, state support was unanimously considered to be an important instrument to protect companies in crisis. It remains to be proven how effective the measures taken by the German state will be in the long term. Some respondents considered it dangerous to artificially finance "dead" companies and predicted that many more insolvencies will occur in quarter 4 of 2020. Ultimately, each of the companies surveyed recognised the risk of infection for itself and took effective measures to prevent a shutdown and thus maintain operations. In this regard, the variety and quality of concepts and measures that were introduced were remarkable and this should be considered as one of the most important tasks of a company during a crisis.

### **6.1.2 Information management**

Measures in this area include communication, collaboration among SC members, information transparency and sharing, culture, and IT systems and real time monitoring.

In all four cases, communication was identified as probably the most important task during a crisis. As little information is available and a high level of uncertainty persists, the ability to make decisions is negatively affected. In such cases communication is essential as a means of obtaining information and thus increases the level of certainty. It thereby increases the effectiveness of decisions and the ability to react to further disturbances. This was particularly important as the pandemic is a very dynamic threat, since conditions are constantly changing, and knowledge is rapidly becoming outdated.

As a crisis like the COVID-19 pandemic was not experienced by any of the respondents before, it was impossible to rely on experiences from the past. Most of the companies worldwide were in a similar situation. Due to this and the high degree of uncertainty at each node of the SC, precise statements, for example, about one's ability to deliver, were impossible to make. As a result, despite the attempts to exchange information and create transparency, often only inaccurate results could be achieved. This also applies to the cross-company collaborative exchange of information, whereas this seems to be aggravated even further since companies, for example, the customers in the automobile industry in case of company D, are becoming more self-centred during the crisis and focus more on their own survival than on the consequences for their partners. On the other side, positive examples are noted as well, for example, interviewee 4 said the collaboration with its suppliers functioned well since they could give approximate information about the coming deliveries and their own situation, etc.

Real time monitoring through IT systems was also mentioned in each case. This helped to organise the available information and to make it transparent for each employee and member of the SC. Still, the available information was obviously limited.

Each company has integrated risk management into their culture and was therefore very aware of the potential consequences of the corona crisis and acted accordingly. The culture of Company A stands out in particular. Through motivating leadership, open communication and transparency about the company's situation, as well as management support in form of guidelines and information, the company has succeeded in uniting the employees and creating high labour productivity. This helped to speed up processes and decisions during the crisis and thus contributed to the effective and efficient response of the company.

### **6.1.3 Supply and transport**

In order to guarantee supply, all companies have acted very similarly. The methods here primarily included proactive measures such as having multiple suppliers, classic inventory management, safety stocks (here: proactive and reactive) and forecasts.

Safety stocks have proved to be beneficial in all cases and have effectively prevented supply shortages. In case of company A, having high stocks was even part of the corporate strategy. Still, some problems occurred.

For example, it could be observed that companies B and D had more difficulties in generating second sources of supply due to their dependence on the OEMs and the high degree of quality standards, bureaucracy, time efforts, and specification levels of the products. As a result, these companies were less flexible during the crisis and could not easily access second sources of supply or increase their stocks by using second sources as, for example, in the case of company A and C. Additionally, respondent 2 stated, that their classic risk management methods, i.e. supplier risk assessment based on vulnerable geographic areas, political instability, etc. have been “useless”. He explained that these methods could not prepare any company for a global pandemic and prevent its consequences, thus the importance of appropriate reactive measures and adaptation was emphasised.

Moreover, during the crisis a close exchange with suppliers was maintained and all companies underlined the importance of communication among the SC partners in general. However, limits were also identified here by respondent 1, for example, as suppliers were often unable to provide accurate reliable information (or did not want to do so because of possible recourse claims). As a result, the applicability of (collaborative) forecasts was heavily impaired too, since they need a certain level of information to be accurate enough and useful for planning purposes. In some cases, flexible product design and transport modes have also helped to mitigate supply problems caused by transport or supplier disruptions. Having access to different transportation modes was crucial for company C, since the majority of its products was shipped by passenger flights, which became a risk during the crisis.

Finally, classic inventory management was used in all cases to generate information that can be used to derive measures regarding stocks, production planning, and the ability to deliver to the customers. Overall, the traditional risk mitigation measures have succeeded in securing the supply in each case, whereas in some cases specific measures, such as multiple sourcing (especially reactive), and forecasts were less effective than in others.

### **6.1.4 Production and operations**

Measures to ensure the continuity of operations and production included flexible adaptation of operations to the crisis, managing orders and capacity, and having flexible facilities.



One of the standard approaches during pandemics is home office operations. Not only does home office ensure the continuity of operations but also decreases the risk of infections among employees.

A lot of the process adaptations were connected to hygiene measures. Therefore, companies have introduced various concepts, as described during the single case analysis, such as separation of shifts and break times, introduction of A and B work teams, ensuring safety distance in production areas, provision of protective gear, and others. Consequently, all companies have managed to protect their operations against the potential impacts of infections. Indeed, some companies, such as company B, needed more time and effort to reconfigure their processes than others, for example, company C. Several reasons play a role here, for example, the complexity of the processes, the pre-crisis use of cloud-based processes, the need for human interaction within the processes, and the availability of IT equipment, systems and capabilities.

Another measure applied during the crisis is the flexible use of facilities, which allowed company D to move capacity from the disrupted plant in China to another plant in Indonesia, thereby reducing the impact of the downtime in China. However, respondent 1 explained that this approach is not practicable for smaller companies like Company A because of the high costs associated with additional facilities.

Further, each company was managing their orders to match demand fluctuations and to ensure a certain level of capacity utilisation. In this regard, the prioritisation of orders was the most often named measure across all four cases. In case of company D, it was observed that the application of postponement of orders was subject to the conditions of the contracts and therefore limited.

Every company had to adjust their capacity to some extent, especially during the lockdown periods. While capacity management was helping to stabilize the overall utilisation in production, it was bounded by the demand in the different industries. Especially company B and D are threatened low demand.

### **6.1.5 Demand**

The analysis of the case studies showed that the demand situation was the major problem during the crisis. Demand declines, difficulties in reaching the customers, and political restrictions that hindered the companies to provide their products and services have created massive disruptions. Among the measures to mitigate these problems are market dispersion, a diversified product portfolio and different customer segments, the ability to reach customers through different distribution channels, and classic customer management.

The investigation of the cases has shown that each company supplies geographically dispersed markets, but with diverging levels of success. Since the crisis is global, the geographical dispersion of markets is in any case not as effective as in other disruption situations as all international markets are disrupted at the same time. In addition, the different conditions in the various industries are also relevant. It was observed that Company A and C were able to generate enough demand through the strength and stability of the German market to compensate for the losses from other international markets. However, the situation was different for company B and D, as the aviation and automotive industry in Germany have also experienced severe declines during the crisis.

Another measure that helped to mitigate the demand disruptions during the crisis was having a diversified product portfolio. This was particularly effective for company B, as it was able to partly compensate for the losses in the aviation sector by processing the orders from the industrial gas turbine sector.

While Company C did not benefit from a diversified product portfolio, it was the only company that could reach its customers through different distribution channels, in this case e-commerce. This approach has proven to be particularly useful in pandemic situations, as it reduces the risk of infection and circumvents political restrictions such as compulsory shop closures. This was also noticeable across almost every other online retailer during the crisis, as the demand increased tremendously.

Finally, each company has managed their customers according to their possibilities. In this regard, the main activity was communication with customers to receive information about their status, needs and potential demand. It also comprised activities to generate demand, for example, by acquisition of new customers. Again, this was achieved by company C, as it generated demand from customers who bought their eyewear in offline shops before the crisis and then started using the e-commerce channel during the crisis. However, the other companies were not easily able to generate new demand. In case of company D, a lot of bureaucracy presents a hurdle that prevents the company from quickly generating new customers. Company B's customers are threatened by insolvency and thus in an extremely vulnerable position, and company A was unable to generate demand in the building sector on its own and was rather surprised when the demand from hospitals suddenly increased.

Although some measures helped the companies to mitigate the impacts on demand, this area was difficult to manage for each enterprise. Company C had the advantage that its products are relatively unaffected by the pandemic. Consequently, it had less difficulties in this regard. Meanwhile, companies B and D are still in an extremely vulnerable position as their products and services were severely affected by the crisis.

## **6.2 Analysis of pandemic-specific factors**

The respondents were asked some pandemic-specific questions during the interviews. These were aimed at deriving specific factors of a pandemic that are affecting the possibilities of companies to manage the crisis. The results are presented in Fig. 11. The factors are linked with examples that either enhance the capabilities of companies during the crisis or reduce them. This approach is adopted from Blackhurst et al. (2011). Note that the factors were named by the respondents during the interviews and represent their personal view. This means that some of the factors are important for risk management in general, but they were stressed again during the interviews because they were considered essential in the face of pandemics. Generalisable factors include production, supply sources, IT, culture, and flexibility. They were already discussed during the literature review of this study.

<b>Factor</b>	<b>Enhancers</b>	<b>Reducers</b>
<b>Industry</b>	-Products and service are unaffected from the crisis/political measures, e.g. food, healthcare, technology, e-commerce, etc.	-Products and services are affected from the crisis/political measures, e.g. tourism, aerospace, events, manufacturing, etc.
Production	-High production depth -Low dependence on suppliers -Low product complexity	-High level of outsourced activities - High dependence on suppliers -High product complexity
<b>Processes</b>	-Processes do not require physical interaction with products or people	-Processes require physical interaction with products or people
Sources	-Multiple sources -Geographically dispersed and regional	-Single sources -Geographically centralised -Global -Long delivery times
IT software	-Availability of IT software, devices, skills and knowledge	-IT software, devices, skills and knowledge must be acquired first
Culture and communication	-Communication -Risk awareness -Leadership -Employee training, empowerment	- Lack of communication and transparency -Underestimating risks -Missing guidelines -Unclear responsibilities
Flexibility and responsiveness	-Quick reaction speed -Acquire new customers -Adapt processes to the crisis -Predefined contingency plans, guidelines, clear responsibilities -Ability to quickly launch new products	-Bureaucracy -Complexity of products, services, processes, structures
<b>Customer access</b>	-Multiple distribution channels -Process adaptability	-No alternative ways of accessing customers -Complexity of processes
<b>Government support</b>	-Safety mechanisms -Financial aid -Information communication -Transparency	-Unstable political situation, -No safety mechanisms -No accurate information
<b>Financial situation</b>	-Financial reserves -High price margins -Ability to take out loans	-Little to no financial reserves -Low price margins -Unable to take out loans

Fig. 11: Overview of pandemic specific aspects affecting the crisis management of companies

However, there are five factors that seem pandemic-specific. They include the industry, processes, access to customers, support from the government and the financial situation of a company.

First, the industry of a company strongly affects its ability to cope with the pandemic. This is because the provided products and services are differently impacted by the consequences of the pandemic, such as social distancing, quarantines, lockdowns, other political measures, fear of infections among customers, etc. For example, this study has shown that due to the nature of its products and services, company B was severely impacted, while company C was nearly unaffected because of its offered products and e-commerce business model.

Another relevant aspect is the nature of the processes. Interviewee 3, for example, stated that processes that require physical interaction with people or products are more vulnerable during pandemics than processes that can be performed without being present. For example, processes in the production are more difficult to adjust since protective measures must be implemented first, whereas administrative staff can in most cases perform their work in form of home office without much need for reconfiguration of the processes.

The third factor mentioned is the access to customers. For example, respondent 1 said that during construction stops at the customers' sites, company A was also unable to provide its services because the site was closed. Therefore, no alternative ways to reach customers existed. Meanwhile, company C was able to reach customers through e-commerce when the offline stores were closed. That means having alternative ways of reaching the customer provides the company with more flexibility during the crisis.

The next factor is the support of the government. Four out of four respondents stretched this factor for different reasons. Among these reasons are the provision of support in form of financial aid and information, but also the protection of the people, transparency of the situation and continuous status reports were found to be essential to stabilise the political situation and to give the country a sense of security. This in turn ensures the stability of the market environment.

The last aspect named during the interviews is the financial situation of a company. This aspect is particularly important because of the long-term existence of the pandemic. This means that, unlike in other disruption scenarios, companies may suffer negative cash flows over a long period of time, which increases the relevance of the financial situation to prevent insolvency in the event of pandemics.

## 7 Conclusion

The objective of this study was to investigate how companies in Germany have managed the impacts and mitigated the associated risks of the COVID-19 pandemic. For this purpose, the study aimed at identifying all measures applied by the surveyed companies to increase SC resilience and to examine whether these are traditional measures, i.e. those already existing in the academic literature, or non-traditional measures that have not yet been discussed.

To achieve this objective, the existing literature was first analysed. On the one hand, this was intended to lay the theoretical foundation and, on the other hand, to identify resilience measures that would allow a comparison of theoretical and empirical results during the evaluation. The next step was to conduct empirical research. First, the research design was developed, and the method was determined by which the data would be evaluated. Then, suitable case studies were identified, the interview protocol was developed, appropriate candidates for interviews were contacted, data from the respective cases was collected, and finally the data was evaluated.

This study provides insights into the experiences made by four different companies in Germany during the COVID 19 pandemic. It shows which measures the companies have applied and how successful they mitigated the impacts of the crisis. In addition, this study identified several pandemic-specific aspects that affect the ability of companies to manage the crisis. The analysis of the single cases and comparison with the theoretical data has shown that all methods applied by the investigated companies during the crisis were to be found in the literature in a similar or a marginally different form. Consequently, no non-traditional risk mitigation measures have been identified during this study. Furthermore, the evaluation of the results showed that the companies applied all the resilience measures listed in the literature section. These were not applied simultaneously, i.e. each company implemented a slightly different set of measures, and case-specific differences in the application and effectiveness of the measures between the case studies were identified. The study revealed that all interviewed companies were able to reduce the impacts of disruptions especially in the areas of supply and transport by using traditional methods. However, there were more significant differences between the cases in terms of disturbances in production and demand. Companies B and D are still in a vulnerable position and the respondents said that in some occasions they were unable to take measures to improve their situation. Meanwhile, company A and C have stabilised their operations and are in a more solid position than company B or D. It was also found that some measures were less effective due to different characteristics of the pandemic, across all case studies, and not just in individual cases. Such measures include forecasts, information transparency and information sharing (due to the lack of information and high uncertainty during the pandemic), dispersion of markets (due to the global nature of the pandemic), as well as customer and demand management (due to the inability of some companies to influence the demand of their customers during the pandemic). In contrast, measures that were commonly applied in all cases and effective during the pandemic include the implementation of protection concepts, the initiation of financial measures, and the support from governments. Finally, this study has identified the factors industry, processes, customer access, financial situation and government support which, according to the experts, influence the ability of companies to mitigate risks during pandemics.

The limitations of this study begin with the case samples. Depending on their job positions, the chosen interviewees have a biased view on the industry, the processes within the company,

and have set their focus on different problems. Also, the data collection in form of telephone interviews prevents the observation of nonverbal communication. Additionally, because of the tight schedules of the interviewees the interviews are limited in time, which results in a limited amount of collected data. Further, due to the small number of cases and the specific characteristics of each case, the results are neither comprehensive nor can they be generalised to any other company. In addition, despite the non-disclosure agreement and clarification on the purpose of the thesis some data was not revealed by the companies and the cases had to be made anonymous. Finally, this study has limited the duration of the research on the time from the beginning of the COVID-19 pandemic in early 2020 to approximately August 2020. In addition, due to the constantly changing information on the object of investigation, namely the Corona crisis, it must be noted that this study has limited itself to the key points that were relevant during the creation of this thesis and thus might miss information that has emerged during later stages of the crisis.

This study can be used as a starting point for further empirical studies that explore other industries and set different priorities in order to achieve comparability and transferability of the various findings. Further interesting research avenues include the investigation of companies that were especially severely hit or did not survive the crisis and elaborate why they failed in mitigating the impacts of the pandemic, in order to derive measures that prevent such outcomes in the future. Another question is how companies outside Germany have managed the crisis without state aid and what measures have been introduced to address the crisis. In addition, one could investigate the short-term impacts and compare them to the long-term impacts of the crisis after the pandemic is over. In this context, it would also be interesting to see, for example, whether the support of the German government has been successful in securing the companies or whether it has only postponed the date of insolvency.

## 8 Literature

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## 9 List of Figures

<b>Fig.1:</b> Michael Porter's Value Chain, .....	p.3
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<b>Fig. 2:</b> Supply Chain, .....	p. 4
D. Ivanov, A. Tsipoulanidis, J Schönberger (2019): Global Supply Chain and Operations Management, Springer Texts in Business and Economics, Switzerland, p.8	
<b>Fig. 3:</b> Efficient vs Responsive Supply Chain, .....	p.5
M. L. Fisher (1997): What Is the Right Supply Chain for Your Product? Harvard Business Review. Mar/Apr97, Vol. 75 Issue 2, p105-116	
<b>Fig. 4:</b> Supply chain risk characteristics, .....	p. 6
I, Heckmann, (2016): Towards supply chain risk analytics. Springer, Wiesbaden, p. 52	
<b>Fig. 5:</b> Phases of disruptions and performance analysis, .....	p. 9
D. Ivanov, (2018): Structural dynamics and resilience in supply chain risk management. New York: Springer, p. 52	
<b>Fig. 6:</b> Proactive and Reactive Supply Chain resilience measures, .....	p. 14
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Pettit, T.J., Fiksel, J. and Croxton, K.L. (2010), Ensuring Supply Chain Resilience: Development of a conceptual framework. Journal of Business Logistics, 31: p. 12	
<b>Fig. 7:</b> Company Overview, .....	p. 21
Hsi Yueh Chen, Ajay Das, Dmitry Ivanov (2019): Building resilience and managing post-disruption supply chain recovery: Lessons from the information and communication technology industry, International Journal of Information Management, Volume 49, p. 333	
<b>Fig. 8:</b> Interviewee Overview, .....	p. 21
Hsi Yueh Chen, Ajay Das, Dmitry Ivanov (2019): Building resilience and managing post-disruption supply chain recovery: Lessons from the information and communication technology industry, International Journal of Information Management, Volume 49, p. 332	
<b>Fig. 9:</b> Overview of the single cases, .....	p. 32
<b>Fig. 10:</b> Overview of empirically identified risk mitigation measures, .....	p. 34
<b>Fig. 11:</b> Overview of pandemic specific aspects affecting the crisis management of companies, .....	p. 40

## 10 Appendix

### Interview Protocol

#### Introduction

The research deals with the topic of supply chain risk management of companies in the face of severe disruptions such as the Corona crisis. The aim of the research is to use empirical research and form case studies of companies to investigate what measures they have taken and are taking during the pandemic to ensure the operation of the supply chain and thus the continuity of the company.

#### Research Questions (Level 2 Questions, Yin 2013, pp. 90-91)

Questions that the research seeks to answer:

- How do enterprises react on the corona pandemic in order to mitigate risk?
- Which traditional risk mitigation measures were applied in the corona crisis and how?
- Are non-traditional risk mitigation measures applied in the corona crisis?

#### Data Collection Questions (Level 1 Questions, Yin 2013, pp. 90-91)

These questions were asked during the interviews. Note that because of the semi structured approach the interviews also include spontaneous questions, depending on the case, that are not included in the protocol.

##### A General information

1. Please provide your title and years of experience in supply chain management.
2. Please provide a brief description of your supply chain design. (Locations of suppliers and facilities, customers; general flow of information and material flow)
3. Please provide general information about your company: industry, products/services offered, number of employees, annual profit/turnover, number of customers

##### B Questions on mitigation measures

4. What disruptions have you experienced in your company due to Corona? (Focus on Supply, Transport, Production, and Demand disruptions)
5. How did you manage these disruptions in your company?
6. What were other risks you had to deal with?
7. How did you mitigate those risks?
8. Why do you think some companies have struggled/are struggling more than others during the crisis?
9. Can you give a few examples of measures that have worked for you in other crisis situations but were not applicable during Corona?
10. What has helped your company to survive the corona crisis?
11. What role does risk management play in your company?
12. What is your opinion about the role of the state in the face of pandemics?

## **Declaration of Independence**

I declare that I wrote this thesis independently and on my own. I clearly marked any language or ideas borrowed from other sources as not my own and documented their sources. The thesis does not contain any work that I have handed in or have had graded as a Prüfungsleistung earlier on.

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My name: Tobias Windel

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Date: 11<sup>th</sup> of September 2020

Signature: 