A cause-effect diagram to support the management of the financial impact of a supply chain disruption
Disruption Analyses of the Supply Chain due to Corona Virus, based on actual information, with focus on Manufacturing Industry

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A cause-effect diagram to support the management of the financial impact of a supply chain disruption

Disruption Analyses of the Supply Chain due to Corona Virus, based on actual information, with focus on Manufacturing Industry

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Summary

The vulnerability of today’s supply chains has significantly increased due to the emergence of ever more complex supply networks combined with an increasingly turbulent business environment. In addition, the globalization of business transactions has increased the risks exposure of supply networks even more (Durach, Glasen, & Straube, 2017). There are two different types of risks a company can encounter; internal risks and external risks (Wu, Blackhurst & Chidambaram, 2006). The focus of this research will be on disruptions in the supply chain due to external risks, more specifically due to the Corona pandemic. This pandemic has adversely affected every economy in the world. Not only has it changed the way people work and travel, it also heavily disrupted international supply chains and networks.

The Corona pandemic reveals an important moment in time to evaluate how supply chain disruptions can be managed or even prevented. To investigate the impact of the Corona crisis on supply chains, a research project has been set-up by the Eindhoven University of Technology called DASCOVIMI: ‘Disruption analyses of the supply chain due to the Corona Virus, based on actual information, with focus on Manufacturing Industry’. It is an explorative research which is a first step into analysing and understanding disruptions to supply chains and how to deal with them in a more effective manner. The business context in which the DASCOVIMI project is conducted is the manufacturing industry and it is executed in collaboration with four consortium companies.

As an individual contribution to the DASCOVIMI project, this master thesis will focus especially on the financial impact of the Corona crisis and how financial variables can be managed to be able to recover from the supply chain disruption. Therefore, the research question of this master thesis is stated as follows:

*How can companies manage certain financial variables to prepare for, or recover from, a supply chain disruption like the Corona crisis?*

To be able to answer this research question, information is gathered and analysed qualitatively and quantitatively. First, a general idea about the impact of the Corona crisis on the financial performance of firms is obtained by performing a quantitative analysis of publicly available data. Thereafter, case studies are performed with the four consortium companies to obtain experiential knowledge on the (financial) impact of the pandemic and the actions taken to mitigate its impact and start recovery.

A quantitative analysis is performed to examine the effect of the Corona crisis on the financial performance of companies by using publicly available data related to stock prices and market prices. For a sample of 89 firms active in four different industries, abnormal returns associated with the Corona crisis were estimated and checked for statistical significance. The event study methodology described by Hendricks, Jacobs and Singhal (2020), which uses the market model, is followed to estimate those abnormal returns. From this analysis, it can be concluded that the Corona crisis had a negative effect on the financial performance of companies. Firms lost on average 31.77% of their shareholder value as a result of the Corona crisis during the one-month period after the first containment measures in Europe. A comparison between the four different industries indicated that the negative financial impact of the Corona crisis was less for companies in the Food & Retail industry.

For the case studies, in-depth interviews were conducted with the four consortium companies. Besides conducting interviews, a survey has been made and sent out to European Supply Chain Forum (ESCF) members to gather information about the impact of the Corona crisis on more...
companies than only the DASCOVIMI partners. High-level insights have been obtained into how the COVID-19 pandemic has impacted the manufacturing industry, as well as the logistics sector.

The impact on a firm’s operations is dependent on the impact on markets in which it is active and the suppliers it works with. Local rules and decisions made by governments also led to many disruptions. The lack of a centralized European set of rules was a major cause of this. Work shifted from the office to home, bringing several challenges for employees, their families as well as firms. However, it did not cause severe operational problems for jobs outside the production, warehousing and transportation “shop floor domains”. Of the four firms studied in detail, it was observed that three of them were not severely hit by the pandemic. A few saw dips in demand and revenue, but they were able to return to pre-pandemic levels by the summer. Some even argued that having less involvement of indirect personnel (e.g. managers) increased their productivity. Firms with a contingency plan were able to react faster and more effectively than others. It was necessary for firms to be creative, flexible and innovative in managing their organization during the disruption. Flexibility and the ability to quickly adapt to changes due to the disruption had been crucial for effective cost management. Additionally, data transparency and visibility were very important. Network level visualization can significantly improve planning and survival of a firm.

Based on the insights from the interviews and survey results, a cause-effect (CE) diagram is created. This CE diagram gives companies insights into the different causal relations that have created possible problems during the Corona crisis. It describes the causal chains between the pandemic occurrence and its impact on revenue, costs and thereby on profit margin, which eventually determines the viability of a company and the supply chains it participates in. The CE diagram is both a tool that supports understanding of what has happened in the supply chain, and a tool that supports the identification of measures to be taken to recover from the pandemic and measures that can mitigate the (financial) impact of the pandemic.

As a last step, recommendations for actions in the discovery, recovery, and redesign phases of a disruption were derived based on the lessons learned from the interviews, the survey results and the CE diagram. These recommendations provide guidance when facing the challenges posed by a major supply chain disruption:

**Discovery**

- Critically analyse and monitor internal performance and external information.

**Recovery**

- Make changes to processes on the spot, for companies that have (some) flexibility in their operational processes.
- Ensure that there is transparency in the supply chain, or to increase transparency during the disruption, to improve recovery.
- Reduce costs by scaling down on flexible assets and personnel, for companies that have a light assets and personnel strategy.
- Analyse governmental regulations on a regular basis such that operations can be managed and adjusted, and that they meet the restrictions in the respective countries.
- Not solely focus on internal business, but also monitor suppliers, customers and competitors to improve recovery.
- Focus on employees during a disruption, where employees are being informed and involved, and where (informal) social contacts are being retained.
Redesign

- Evaluate the ICT infrastructure and make sure that it is reliable and up to date.
- Have a clear documentation and representation of processes related to operations management, with an information system in place to support the operational processes.
- Have a contingency plan in place for when a disruption happens.
- Have strategic emergency stock to be able to reduce the impact of a disruption.
- Evaluate market strategy and have a diversified customer base if possible.
- Make sure there is a partnership atmosphere in the whole supply chain.
- Evaluate how suppliers and customers behaved and how reliable they were during the crisis.
- Evaluate components, processes and management, how they changed during the crisis, and decide whether permanent changes need to be made.
- Evaluate (insurance) contracts to be sure that you have reliable (insurance) partners with reliable contracts.
Preface

This thesis marks the end of my career as a student at Eindhoven University of Technology. In the past years, I have learned so many new and interesting things. Besides that, I also really enjoyed my student life and am grateful to have met so many amazing people who I can call my friends. I would like to thank a few people that have been part of my journey in finishing this thesis.

First of all, I would like to thank my supervisor Karel van Donselaar for his guidance and valuable feedback and suggestions during the entire project. Moreover, I would like to thank Edwin Wenink for providing me the opportunity to be part of the DASCOVIMI project. He was always there to motivate me and to discuss or brainstorm about ideas on how to proceed. I also really liked the close collaboration with my other DASCOVIMI student members Valerie Geelen and Romy Olislagers. Without you, the past few months would have been much less productive and fun. Furthermore, I would also like to thank the scientific staff from our DASCOVIMI team: Ton de Kok, Laura Genga, Shaunak Dabadghao and Ravi Ranjan. We had a lot of valuable workshops together and I really appreciate the input that you brought in from your own field of research and the critical feedback which definitely improved the quality of the project. You were always there to help me.

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Marliek Raadsheer

Eindhoven, November 2020
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1. Introduction

1.1 Context

The vulnerability of today’s supply chains has significantly increased due to the emergence of ever more complex supply networks combined with an increasingly turbulent business environment. In addition, the globalization of business transactions has increased the risks’ exposure of supply networks even more. Identifying effective supply chain risk management strategies has therefore become very important in contemporary supply chain studies (Durach, Glasen, & Straube, 2017). Additionally, global supply chains are more risky than domestic supply chains due to numerous links interconnecting a wide network of companies. These links are prone to disruptions and disasters, leading to higher risks and making risk management more difficult (Manuj & Mentzer, 2008).

Global supply chains are a source of competitive advantages, as they provide firms access to cheap labour and raw materials, better financing opportunities, larger product markets, arbitrage opportunities and additional stimulus offered by host governments to attract foreign capital (Manuj & Mentzer, 2008). Additionally, today’s supply chains have moved from the traditional “just in case” philosophy to the adoption of “just in time”. The resulting supply chains have become leaner and more profitable, since the capital that was previously tied up in inventory, can now be used for other profitable activities (Natarajarathinam, Capar, & Narayanan, 2009). However, despite having competitive advantages and operating leaner, a global and just-in-time supply chain also entails risks and uncertainties. Especially since most companies develop plans to protect against recurrent low-impact risks and ignore high-impact and low likelihood risks. This in turn resulted in supply chains being more vulnerable to disruptions caused by crises (Manuj & Mentzer, 2008). To maintain the profitability of the supply chain, they must be able to quickly respond to external as well as internal risk events, and they have to be resilient to unexpected catastrophic events (Aqlan & Lam, 2015).

As Aqlan and Lam (2015) declare, there are two different types of risks a company can encounter. Wu, Blackhurst and Chidambaram (2006) classify these risks as internal or external, and the degree to which the risks are controllable. According to El-Sayegh (2008), internal risks are usually under control of the company, whereas external risks are beyond the company’s control. An example of an internal controllable risk is the quality of a product. An example of an external controllable risk is the selection of next tier supplier. External uncontrollable risks can be categorized among three different groups: natural/man-made disasters, such as hurricanes, earthquake and pandemic; political/economic stability, such as a new government or changes in rules and regulations; and market characteristics, such as market growth and market size (Wu et al., 2006).

The focus of this research will be on disruptions in the supply chain due to external risks. The Corona pandemic reveals an important moment in time to evaluate how supply chain disruptions can be managed or even prevented. Therefore, the purpose is to provide insights on disruptions in the supply chain due to external risks.
1.2 Overall problem description
This master thesis is performed during the Corona crisis. To investigate the impact of the Corona crisis on supply chains, a research project has been set-up by the Eindhoven University of Technology. This project is called DASCOVIMI which stands for: ‘Disruption analyses of the supply chain due to the Corona Virus, based on actual information, with focus on Manufacturing Industry’. The DASCOVIMI project team consisted of a project manager, four members of the academic staff of the department Industrial Engineering & Innovation Sciences and three students (including me), who were working on their bachelor’s thesis and master’s theses. The students worked in close collaboration during the whole project and worked out results/reports together, but they all had their individual deliverables and contributions to the DASCOVIMI project.

The Corona pandemic has a major impact on supply chains worldwide and reveals mutual dependencies in global supply chains. Like in the 2011 Tsunami in Japan, this pandemic reveals the mutual dependencies in global supply chains on which the Dutch economy depends and in which Dutch industries participate. It has resulted in Dutch companies coming to a hold, because suppliers could not deliver parts or because they have lost the major part of their revenues as market demand dropped dramatically. Furthermore, their employees were not allowed to work. This in turn resulted in terminating contracts with flex workers and sending home part of the permanent employees.

Starting up production in supply chains that are in total disarray is not a straightforward task. Scenarios are needed about market recovery to be able to start up supply chains. These market scenarios drive the need for products and parts for the months after start-up. In turn, these drive the need for resources, such as workers, equipment and logistics services. In addition, all activities and transactions for starting up require cash. The starting up of supply chains is constrained by the Corona regulations that should prevent a next break-out of the pandemic. This implies constraints on resource usage due to the 1.5-meter social distancing. These constraints affect production capacity as well as (public) transportation capacity to move workers from home to production and distribution sites. Furthermore, as supply chains have become more and more global, the supply chains are facing different Corona regulations in different countries with different evolution paths when starting up. Moreover, since most companies have a bad cash position due to drops in revenues and continuing payments to employees, starting up is constrained by cash availability. To overcome and tackle these challenges, innovative thinking and insights are necessary. Especially now that numerous supply chains have been disrupted due to the Corona pandemic, it is an important moment in time to evaluate how these supply chain disruptions can be managed in the future.

Current scientific literature does not provide the knowledge and tools to address the issues to be dealt with in the short-term for supply chain recovery from a pandemic or similar major global supply chain disruptions. The DASCOVIMI project aims to start filling this gap by focusing on qualitative insights, and to some extend (descriptive) quantitative analysis. It is an explorative research which is a first step into analysing and understanding disruptions to supply chains and how to deal with them in a more effective manner. The project is intended as a preliminary study for larger follow-up projects. In order to focus on developing detailed insights into all relevant aspects of supply chain disruption management, it is decided to exclude sustainability aspects as explicit objective in this first explorative research, primarily as research resources are limited (DASCOVIMI, 2020).
1.3 Consortium companies
The business context in which the DASCOVIMI project is conducted is the manufacturing industry and it applies to the supply chains (i.e. manufacturers) as well as to nodes and corridors (i.e. logistic service providers). This research is executed in collaboration with four companies: Company A, Company B, Company C and Company D. These companies provided actual market and supply chain insights in combination with high-level company data.

1.4 Joint work
As mentioned above, the DASCOVIMI student members (including me) worked in close collaboration during the whole project and worked out results together. The results described in section 5.1, 5.4, 6 and Appendices A, B, C and D are joint work. Furthermore, the literature summary in section 2 is based on the literature review of fellow DASCOVIMI student member Valerie Geelen on supply chain disruption management. Lastly, the explanations and data analyses described in section 5.3 are partially written by me and partially by Valerie Geelen (this partition is indicated in the section itself). All other sections are own work.

1.5 Research question and sub-questions
The DASCOVIMI project is studying how companies recover from shocks such as the Corona crisis. Starting up supply chains after (or during) a pandemic requires (global) supply-chain-wide coordination, as demand, production, logistics, and finance can all be constraining supply chain partners in different ways. These all affect the flow of goods from suppliers to consumers and users. Furthermore, many companies have no experience with recovery from a pandemic of this magnitude.

As an individual contribution to the DASCOVIMI project, this master thesis will focus especially on the financial impact of the Corona crisis and how financial variables can be managed to be able to recover from the supply chain disruption. Shutdowns as a consequence of the Coronavirus have affected all firms, big and small. Although some companies are better prepared than others, where some companies are just lucky, most companies are dealing with some significant problems. Insights can be gained by contrasting the actions taken by companies that recover faster, compared to companies that recover slower. Typically, these actions deal with the proper management of for example margins, revenues, costs and inventories. In addition, these actions can differ between large companies and small companies. For example, larger companies can support their small-scale supply chain partners by paying them earlier. So, efficiently managing certain financial variables can play a crucial role in the recovery of a shock such as the Corona crisis. Therefore, the research question of this master thesis is stated as follows:

How can companies manage certain financial variables to prepare for, or recover from, a supply chain disruption like the Corona crisis?

In order to be able to answer this research question, three sub-questions are formulated. These sub-questions will guide the information gathering process. The following sub-questions are formulated:

- How has the Corona crisis affected the financial performance of companies?
- Which elements influence the impact of a disruption on a company’s financial variables, and how are these elements related?
- What are the different actions taken, including actions regarding financial variables, by firms to recover from the disruption?
2. Summary relevant literature

Before going into any further research concerning disruptions in the supply chain due to external risks, it is important to get a clear understanding of what disruption management actually is. In the existing literature, many definitions can be found, which lead to the following definition of supply chain disruption management: “an unplanned, unanticipated and unintended situation that disrupts the normal flow of goods and materials within the supply chain”. This disruption of the supply chain can expose firms to operational and financial risks (Revilla & Sáenz, 2014; Xiao & Yu, 2006; Macdonald & Corsi, 2013; Durach et al., 2017; Revilla & Saenz, 2017; Tse, Matthews, Tan, Sato & Pongpanich, 2016).

Supply chain disruptions can lead to severe and long-term economic impacts on the supply chain (Brandon‐Jones, Squire, Autry, & Petersen, 2014). Therefore, it is important to mitigate these threats to damp the effect on organizational performance. This can be done by using disruption management to create resilience and robustness. Resilience is the ability of a system to return to its original state or to move to a new, more desirable state after being disturbed (Christopher and Peck, 2004). Robustness is defined as being physically sturdy and being able to retain the same stable situation as before changes occurred (Durach, Wieland & Machuca, 2015). Both resilience and robustness relate to two of the main stages of disruption management as defined by Macdonald & Corsi (2013), namely recovery and redesign (see Figure 1).

![Figure 1: Time-series of evolving disruption (Macdonald & Corsi, 2013)](image)

In each of these stages, in order to mitigate the effects of the supply chain disruption, it is important to find out which elements are important. For resilience, ten articles have been analysed to find out which are the most important elements that it contains. Out of this analysis, it turned out that the four main elements of resilience are flexibility, visibility, collaboration and agility.

Flexibility is the operational ability of a company to adapt to the changing needs of its environment and stakeholders quickly, and with minimum effort (Tukamuhabwa, Stevenson, Busby & Zorzini, 2015).

Visibility refers to the ability to see through the entire supply chain (Christopher & Peck, 2004).

Collaboration is by Scholten and Schilder (2015) found not to be a formative element of supply chain resilience, but rather as an antecedent of flexibility, velocity and visibility. So, collaboration indirectly improves resilience, by improving these constructs. The two main elements of collaboration are trust and information sharing between the parties involved (Kamalahmadi & Parast, 2016).
The last element that is needed for successful supply chain resilience is agility. This is the strategic ability to respond quickly to unpredictable changes in demand or supply (Christopher & Peck, 2004). Whereas flexibility concerns the capability to respond immediately within the boundaries of available resources, agility concerns the capability to strategically create resource availability that enables the operational flexibility needed to maintain the market position.

In disruption management, there are two main strategies that can be used, namely a proactive strategy and a reactive strategy (Grötsch, Blome & Schleper, 2013). A proactive strategy is related to preparedness for the disruption by for example an action plan or by creating worst-case scenarios. Important elements in this strategy are collaboration, human resource management, inventory management, predefined decision plans, redundancy and visibility (Hohenstein et al., 2015). A proactive strategy often facilitates an easier and quicker response to the disruption, since visibility should lead to early warnings (Grötsch et al., 2013). A proactive strategy creates the agility needed to manoeuvre. On the other hand, a reactive strategy entails taking action after the disruption has already happened and it is often associated with redundancies and safety stocks. Important elements of a reactive strategy are flexibility, collaboration, human resource management and redundancy (Hohenstein et al., 2015).

Furthermore, there are several trade-offs that need to be made in disruption management. These are trade-offs related to supplier selection, inventory management and redundancy versus efficiency (Sheffi, 2001). The main trade-off that is made concerning supplier selection is whether to choose a domestic or a foreign supplier. When choosing a foreign supplier, the disruption probability will be higher due to longer lead times and vulnerability to disruptions in the transportation system, however the price of a foreign supplier is often lower than the price of a domestic supplier (Sawik, 2014). A graphical representation of this is shown in Figure 2. It is also possible to make use of dual sourcing, which is making use of two suppliers. When combining foreign and local suppliers, the incremental cost of using a local supplier is the premium that is paid in order to reduce the risk of supply-chain disruption (Sheffi, 2001).

In inventory management, the main trade-off that needs to be made in case of disruptions is whether to keep using lean operations such as the just-in-time policy or to increase the amount of safety stock and move to just-in-case processes. Sheffi (2001) proposes a solution that separates the normal business uncertainties from the risk associated with big disruptions caused by external factors. So, additional to normal safety stock, manufacturers should keep a ‘strategic emergency stock’ that can be used in case of an extreme disruption. Additionally, Atan and Snyder (2012) did research on the use of inventory to mitigate supply chain disruptions. Their main finding is that
mitigating disruptions requires holding more inventory, which provides a buffer against uncertainty introduced by disruptions. The amount of this extra inventory depends on the severity of the disruptions, in addition to the business objectives of the firm.

The third trade-off that needs to be made in disruption management is the trade-off between redundancy and efficiency. Redundancy involves the strategic and selective use of spare capacity and inventory that can be used during a disruption. This is contrary to the belief of efficiency, meaning that surplus capacity and inventory is only seen as waste and is therefore undesirable (Christopher & Peck, 2004). Most of the existing literature agrees that it is good to have some surplus capacity or inventory. However, because of the high costs that are often accompanied with it, this redundancy should be handled selective and strategically, and it is not preferred to move entirely from efficient, lean processes back to a full just-in-case strategy (Christopher and Peck, 2004; Tukamuhabwa et al., 2015).
3. Research methodology

This section describes the research design of this master thesis project. Information is gathered and analysed qualitatively and quantitatively to be able to answer the sub-questions and eventually the research question. The project can be partitioned into two main parts. First, a general idea about the impact of the Corona crisis on the financial performance of firms was obtained by performing a quantitative analysis of publicly available data. Thereafter, case studies were performed with the consortium companies to obtain experiential knowledge on the (financial) impact of the pandemic and the actions taken to mitigate its impact and start recovery.

Literature review

Before starting with the qualitative and quantitative analyses, the literature review about supply chain disruptions from one of the students in the project (Geelen, 2020) was read to gain a clear understanding of supply chain disruptions. A summary of this literature review has already been presented in section 2.

Impact on financial performance

As a first step, a quantitative analysis was performed to examine the effect of the Corona crisis on the financial performance of companies by using publicly available data related to stock prices and market prices. This analysis provides the answer to the first sub-question of this thesis. A detailed description of the methodology that is used for the analysis is described in the next section ‘Analysis of impact on financial performance’.

Case studies

The four companies involved, mentioned in the section 1, have provided detailed information and some data for the research project. At the start, it was essential to explain to these companies what the project aims to achieve, what is expected from them and in which phase of the project they are needed, and to discuss what the companies expect from the project. For this purpose, an introductory meeting was held with each company individually.

Thereafter, the qualitative phase of the project began. Interviews were conducted with each company. The aim of these interviews was to gather information to analyse and get an in-depth understanding of the 1st and 2nd tier supply network. It is important to have a clear understanding about which companies are involved in the supply network and what the multi-tier supply network looks like, and which role these companies have in this network. Furthermore, the interviews were intended to gather detailed information about the impact of the Corona crisis on the supply chain and operations of the company, as well as the challenges during the Corona crisis. The method of research used for the interview, was a semi-structured interview. An interview template was created containing open questions for several subjects to be explored. In the setup of the interview template, a supply chain perspective was chosen and the value chain model of Porter (1985) was used to specify the internal aspects to be discussed. The value chain model is a method for decomposing the firm into strategically important activities. With its generic categories of activities, the overall value-creating logic of the value chain is valid in all industries (Porter, 1985). Two versions of the interview template have been made, one for the manufacturers and one for the logistics service providers (LSP). It is chosen to make two versions because the questions that are applicable may differ. For instance, a logistic service provider does not produce any products and therefore production related questions should not be asked. Both interview templates can be found in Appendices A and B.
During the interview, the responses to the questions were carefully noted down, such that relevant information could easily be retrieved afterwards. To be able to write out the answers more extensively, the interview was recorded, with permissions of the interviewee, with a mobile phone. The notes were transcribed within 24 hours of each interview and were sent to the interviewee for verification. After all interviews were conducted and all the notes of the interviews were worked out, a systematic review approach was used to determine the most frequently and striking mentioned aspects for each company: the notes of each interview were analysed by three independent reviewers to prevent biases. These most frequently and striking mentioned aspects were structured using a SWOT analysis. Based on this analysis, the qualitative insights from the interviews were written down as lessons learned per company. Furthermore, the findings were compared with the existing literature which is presented in section 2. For verification, the SWOT analysis and the lessons learned were sent to the interviewees and adaptions were made if necessary.

Based on the lessons learned per company, a cause-effect (CE) diagram per company was created. According to Donndelinger and Van Dine (1996), a cause-effect diagram could be used to address conflict issues at all levels of the organization. It is designed to examine the causes of a particular issue, problem, or process. By creating a cause-effect diagram for each company, the aspects mentioned in the lessons learned for each company are integrated into a network of causal relations. Each CE diagram was discussed with the corresponding company for verification and adaptions were made if necessary. The CE diagrams per company with a short description can be found in Appendix C.

Thereafter, during a number of workshops to stimulate out-of-the-box thinking, the four individual cause-effect diagrams were combined, and the most important aspects were presented in one generic cause-effect diagram. Each element in the generic CE diagram was carefully defined, i.e. unambiguously. This diagram aims to capture all causality chains starting from the occurrence of the Corona pandemic. According to the literature presented in section 2, it is important to discover problems related to disruptions in an early stage. A cause-effect diagram is a useful method to discover the causes of problems which is an important element that contributes to the recovery phase after a disruption occurs. The generic CE diagram gives companies insights into the different causal relations that have created possible problems during the Corona crisis. Once companies have these insights, they can prepare themselves better for future disruptions, which makes them more robust. In an interactive section with the consortium partners, the generic CE diagram has been discussed to make sure that all elements were clear and understandable for businesspeople.

Besides conducting interviews, a survey has been made and sent out to European Supply Chain Forum (ESCF) members to gather information about the impact of the Corona crisis on more companies than only the DASCOVIMI partners. Based on the interview template and the findings of the interviews, the survey was created. Additionally, the sub-questions of this research were considered and used as input for the formulation of survey questions. The questions in the survey are mostly closed-form: binary questions, 4-point Likert scale questions, check-box questions and multiple-choice questions. In some surveys, scales are truncated to an even number of categories to eliminate the neutral option (Allen & Seaman, 2007). In this research, it was decided to use a 4-point Likert scale to avoid people choosing neutral answers as well. For several questions, the option ‘Other’ is given, so the companies could provide own additions. Furthermore, there are some open questions where companies can fill in numbers (percentages) to indicate changes in certain
parameters and write sentences to explain plans for changes. In Appendix D, the survey template and results can be found. The answers to the survey questions resulted in information that is analysed in a quantitative way. These results were used to verify and complement the findings of the interviews, and with that generic CE diagram.

In addition to the definition of each element in the generic CE diagram, descriptive data analysis has been performed for some of the elements in the CE diagram. This has been done for related data that is received from the involved companies in the DASCOVIMI project. The companies provided data regarding orders, the supplier KPI ‘On Time in Full’ (OTIF) and financial statements. Since this thesis focusses on the financial impact of the Corona crisis, data regarding the financial statements were analysed. An attempt has been made to verify the information obtained from the interviews and to describe the impact of the Corona pandemic on certain financial variables for the consortium companies by making insightful graphs based on the data in Excel. Again, the data analyses were discussed with the companies for correctness.

Based on the findings of the described analyses above, logical reasoning and existing literature, the generic CE diagram was complemented with general relations between the elements. These relations give companies insights on the direction of change that is expected when there is a change in another element in the CE diagram.

As a last step, recommendations for actions in the discovery, recovery, and redesign phases of a disruption were derived based on the lessons learned, the survey results and the generic CE diagram. These recommendations were validated with the consortium companies and where needed, reformulated.

It should be noted that an exploratory research approach is used during the DASCOVIMI project. This is the process of investigating a problem that has not been studied or thoroughly investigated in the past. The explorative research is based on the information from the semi-structured interviews with the different consortium companies and the descriptive analysis of the received data from those companies. These case studies will provide a comprehensive overview of the relevant aspects and actual problems during the Corona disruption and when starting up supply chains after the Corona disruption. Findings were complemented with the analysis of the survey data. The research will give first insights for companies on how to act when a disruption happens and provides directions for further research into disruption management.
4. Analysis of impact on financial performance

As described in the overall problem description, the Corona crisis impacts firms in multiple ways. In this section, the effect of the Corona pandemic on the financial performance of firms is analysed quantitatively. To measure financial performance of firms, changes in stock prices (shareholder value) are examined. Since the Corona pandemic resulted in people (and thus employees) being ill, changes in the way of working at companies because of the restrictions imposed by the government and even lockdowns, it is expected that a negative effect will be found. This leads to the first hypothesis that will be analysed:

**H1. The Corona crisis will result in a negative stock market reaction**

Sample

The sample that is used for the analysis consists of 89 publicly traded firms. Only firms that are located and/or traded on stock markets in Europe or the United States were included (see methodology of analysis). In addition, a firm’s stock price information had to be available in the database of Yahoo! Finance to be included. The firms in the sample were selected based on recognition of the firm’s name on lists that mention publicly traded firms in four different industries. The four industries are: Manufacturing, Transport & Logistics, Automotive and Food & Retail. It is chosen to look at these industries, because the DASCOVIMI consortium partners are active in these industries. In Table 1 and Table 2 below, the distribution of firms in the sample according to country where the firms are located and/or traded and according to industry can be found.

<table>
<thead>
<tr>
<th>Country</th>
<th>Occurrences (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>63 (70.79%)</td>
</tr>
<tr>
<td>Germany</td>
<td>8 (8.99%)</td>
</tr>
<tr>
<td>France</td>
<td>6 (6.74%)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>6 (6.74%)</td>
</tr>
<tr>
<td>Great Britain</td>
<td>4 (4.49%)</td>
</tr>
<tr>
<td>Swiss</td>
<td>2 (2.25%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industry</th>
<th>Occurrences (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>32 (35.96%)</td>
</tr>
<tr>
<td>Transport &amp; Logistics</td>
<td>12 (13.48%)</td>
</tr>
<tr>
<td>Automotive</td>
<td>12 (13.48%)</td>
</tr>
<tr>
<td>Food &amp; Retail</td>
<td>33 (37.08%)</td>
</tr>
</tbody>
</table>

Methodology of analysis

The analysis that is performed to investigate the effect of the Corona crisis on the financial performance of firms, follows the methodology described by Hendricks, Jacobs and Singhal (2020). They studied the effect of the 2011 Great East Japan Earthquake on the financial performance of firms by using event study methodology which estimates abnormal returns associated with a specific event. An abnormal return is the difference between a stock price change with the event happening and a stock price change if the event had not happened. In other words, it reflects the return that can be attributed to the event. A stock price change with the event happening is measurable; it is the actual stock return. A stock price change if the event had not happened should be estimated. Changes in stock prices are used in event study methodology because the Efficient Market Hypothesis states that all available and relevant information, and thus the effects of an event, are rapidly reflected in stock prices (Eun & Resnick, 2014).
When performing an event study methodology to estimate abnormal returns, an event period should be chosen. The event period comprises the dates for which abnormal returns are estimated. Since this analysis wants to investigate the financial impact of the event Corona crisis, a date should be determined when the event ‘started’. It was chosen to look at the financial impact on firms in Europe and the United States, because the Corona virus, and its effects, appeared in those regions at approximately the same moment in time and the DASCOVIMI consortium companies are located in these regions. Although the Corona virus was first identified at the end of 2019 in Wuhan, China, the first cases of infection in Europe and the United States were confirmed in February 2020. In an article by Gormsen and Koijen (2020), it is described that the stock markets did not respond much to the outbreak or lockdowns in China. However, after the outbreak of the Corona virus in Europe and the United States at the end of February 2020, and especially after the first lockdown in Italy at February 23, stock markets started to deteriorate. Since February 23, 2020 is a Sunday, the first trading day when markets in Europe and the United States could react to the Corona crisis event is February 24, 2020. Therefore, it was decided to choose February 24, 2020 as the day of the event. This calendar time is converted into event time such that the day of the event (February 24, 2020) is Day 0. For clarification, Day 1 is the first trading day after the event, Day 2 the second trading day after the event, etc. Looking at the stock prices of the market indexes that are dominant in the countries of the sample firms (see Appendix E), and also taking into account the analysis by Gormsen and Koijen (2020), the stock market started to recover around March 20, 2020. March 20, 2020 in event time corresponds to Day 19. Therefore, it was chosen to estimate the abnormal returns on the day of the event as well as the subsequent 19 trading days (Day 0 to Day 19). This 20-day event period covers roughly one month in calendar time, because a calendar week contains 5 trading days. For robustness, results are also reported for a 3-day, a 6-day and a 11-day event period, besides the focus on the 20-day event period.

After the event period has been determined, the abnormal returns can be estimated and the statistical tests to judge their significance can be performed. To estimate abnormal returns, the market model was used. In the market model, the following relation is assumed between stock return and market return

\[ R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}, \]  

(1)

where \( R_{it} \) is the return of stock \( i \) on Day \( t \); \( R_{mt} \) is the market return on Day \( t \); \( \alpha_i \) is the intercept of the relation for stock \( i \); \( \beta_i \) is the systematic risk of stock \( i \), also known as beta, which is an indication for the sensitivity of the return of stock \( i \) to the market return; and \( \epsilon_{it} \) is stock \( i \)'s error term on Day \( t \). \( \beta_i R_{mt} \) represents the portion of the return on stock \( i \) that is attributed to stock market movement and \( \epsilon_{it} \) represents the portion that is unexplained by market movement. For the market returns \( R_{mt} \) for stock \( i \), the market index that is dominant in the country of firm \( i \) is used (see Appendix E for the used market index in a country). Both the stock return and the market return represent a percentual change and is calculated by

\[ R_{it} = \frac{SP_{it} - SP_{it-1}}{SP_{it-1}} \quad (or \quad R_{mt} = \frac{MP_{mt} - MP_{mt-1}}{MP_{mt-1}}) \]  

(2)

where \( SP_{it} \) is the closing price of stock \( i \) on Day \( t \) and \( MP_{mt} \) is the closing price of the market index on Day \( t \).

To estimate \( \hat{\alpha}_i \) and \( \hat{\beta}_i \) for each firm \( i \), ordinary least squares regression is carried out. The dependent variable in the regression analysis was the stock return and the independent variable was the market return. An estimation period of 200 trading days is used, where the estimation period is started 202 trading days (Day -202) before February 24, 2020 and is ended 3 trading days (Day -3) before the day of the event (similar to Hendricks, Jacobs and Singhal (2020)). By using an estimation period of 200
days, it is less likely that country specific events impact the estimation of the parameters. After the estimation of $\alpha_i$ and $\beta_i$, the expected return for firm $i$ on Day $t$ can be estimated as $\hat{\alpha}_i + \hat{\beta}_i R_{mt}$. By calculating the difference between the actual return and the expected return, the abnormal return for firm $i$ on Day $t$ is found. The equation for the abnormal return is therefore

$$A_{it} = R_{it} - (\hat{\alpha}_i + \hat{\beta}_i R_{mt}). \quad (3)$$

It should be noted that the expected return depends on the market return on Day $t$. As can be seen in Appendix E, all market indexes that are used for the market returns experienced an extreme drop after the day of the event on February 24, 2020. So, the actual market returns during the event period, Day 0 to Day 19, are not a good representation of the market returns when the event had not happened. Using these actual market returns in the event period would underestimate the abnormal return that is associated with the Corona crisis event. Therefore, market returns for each market index were simulated for the event period. An assumption was made that the market returns of a respective market index during the pre-event period are a good representation of what would have happened to the market returns when the Corona crisis did not happen. For each day in the event period, Day 0 to Day 19, one market return from the 200 daily market returns of the respective index over the Days -202 through -3 was randomly drawn with replacement. This process has been repeated 1000 times, to get 1000 randomly drawn market returns for each event day. Thereafter, for each event day, the average was taken from those 1000 market returns. This average was used as the market return for a firm $i$ on Day $t$ to estimate the expected return in equation (3) to calculate the abnormal return.

After estimating the abnormal returns for each firm in the sample for each day in the event period, the mean abnormal return for Day $t$ is computed by

$$\bar{A}_t = \frac{\sum_{i=1}^{N} A_{it}}{N}. \quad (4)$$

where $N$ is the number of firms in the sample on Day $t$.

To account for possible cross-sectional dependence in abnormal returns across sample firms, a multiple day test statistic was used that is derived by Hendricks, Jacobs and Singhal (2020). It is based on the test statistic by Brown and Warner (1985) that adjusts for cross-sectional dependence. The mean abnormal return for the 200-day estimation period is computed by

$$\bar{A} = \frac{\sum_{t=-202}^{t=-3} \bar{A}_t}{200}. \quad (5)$$

The standard deviation from the mean daily abnormal returns for the 200-day estimation period is estimated as

$$\hat{S}(\bar{A}_t) = \sqrt{\frac{\sum_{t=-202}^{t=-3} (A_t - \bar{A})^2}{199}}. \quad (6)$$

The cumulative abnormal return (CAR) for a given period $(t_1, t_2)$ is given by

$$CAR(t_1, t_2) = \sum_{t=t_1}^{t_2} \bar{A}_t. \quad (7)$$

The test statistic for a $j$-day event period is

$$TS_j = \frac{\sum_{t=t_1}^{t_2} A_t}{\hat{S}(\bar{A}_t) \sqrt{j}}. \quad (8)$$
To test for the statistical significance of the mean abnormal returns, *t*-tests were used. For each of the four different event periods described above, the CAR and the test statistic were calculated. Thereafter, the statistical significance was determined. The results can be found in the section below.

As a robustness check, the estimated abnormal returns for the sample firms obtained from the market model using simulated market returns are compared with those obtained from the mean-adjusted model. The mean-adjusted model does not require market returns. It assumes that the expected return without the event happening is the average daily stock return of the firm during an estimation period before the event. The abnormal return in the mean-adjusted model is given by

$$A_{it} = R_{it} - \bar{R}_i,$$

(9)

where $\bar{R}_i$ is the average daily stock return of firm $i$ during the estimation period. For each firm in the sample, the average daily return was estimated using pre-event returns from Day -202 to Day -3. Also for the mean-adjusted model, the CAR and the test statistic, and its statistical significance, were calculated for each of the four different event periods. The results are described below.

**Results**

In Table 3, the results of the abnormal returns for the sample firms that can be attributed to the Corona crisis are presented when employing the market model. The results indicate that the Corona crisis had a negative effect on the sample firms. For the 20-day event period (Days (0, 19)), the mean cumulative abnormal return is -31.77%, significant at the 1% level. Also for the other three event periods, the CARs are negative and significant at the 1% level. These results support hypothesis $H1$.

<table>
<thead>
<tr>
<th>Event day(s)</th>
<th>N</th>
<th>Mean</th>
<th>Test statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0,2)</td>
<td>89</td>
<td>-6.19%</td>
<td>-14.32**</td>
</tr>
<tr>
<td>(0,5)</td>
<td>89</td>
<td>-8.78%</td>
<td>-14.37**</td>
</tr>
<tr>
<td>(0,10)</td>
<td>89</td>
<td>-18.77%</td>
<td>-22.69**</td>
</tr>
<tr>
<td>(0,19)</td>
<td>89</td>
<td>-31.77%</td>
<td>-28.49**</td>
</tr>
</tbody>
</table>

Tests are two-tailed: *p<0.05; **p<0.01

In Table 4, the results of the abnormal returns for the sample firms that can be attributed to the Corona crisis are presented when employing the mean-adjusted model. Comparable to the results obtained from the market model, the mean cumulative abnormal return for the 20-day event period is -31.61%, significant at the 1% level. Again, the CARs in the other three event periods are also all negative and significant at the 1% level.

<table>
<thead>
<tr>
<th>Event day(s)</th>
<th>N</th>
<th>Mean</th>
<th>Test statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0,2)</td>
<td>89</td>
<td>-6.12%</td>
<td>-5.01**</td>
</tr>
<tr>
<td>(0,5)</td>
<td>89</td>
<td>-8.72%</td>
<td>-5.04**</td>
</tr>
<tr>
<td>(0,10)</td>
<td>89</td>
<td>-18.71%</td>
<td>-7.99**</td>
</tr>
<tr>
<td>(0,19)</td>
<td>89</td>
<td>-31.61%</td>
<td>-10.01**</td>
</tr>
</tbody>
</table>

Tests are two-tailed: *p<0.05; **p<0.01

To evaluate the robustness of estimating abnormal returns using the market model with simulated market returns, the mean CARs obtained from the market model are compared to the mean CARs obtained from the mean-adjusted model. Two-sample *t*-tests are employed to obtain *t*-statistics for differences in means. In Table 5 below, the difference in means between the mean-adjusted model and the market model can be found for all the event periods, together with the test statistic. None of
the differences in means are statistically significant. This indicates that the results of the two methods are very similar and that the market model with simulated market returns is robust.

Table 5: Comparison of Cumulative Abnormal Returns using the market model versus the mean-adjusted model

<table>
<thead>
<tr>
<th>Event day(s)</th>
<th>Difference to Market model</th>
<th>Mean</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0,2)</td>
<td></td>
<td>0.07%</td>
<td>0.14</td>
</tr>
<tr>
<td>(0,5)</td>
<td></td>
<td>0.06%</td>
<td>0.08</td>
</tr>
<tr>
<td>(0,10)</td>
<td></td>
<td>0.06%</td>
<td>0.04</td>
</tr>
<tr>
<td>(0,19)</td>
<td></td>
<td>0.16%</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Tests are two-tailed: *p<0.05; **p<0.01

As described above, the firms in the sample are from four different industries. It is interesting to examine what the financial effect of the Corona crisis has been on the firms in each industry separately and whether there is a difference between the industries. At the start of the Corona crisis (February – March 2020), people started to hoard food and other essentials (Preston, 2020). This might suggest that the Food & Retail industry is less impacted compared to the other industries, leading to the second hypothesis:

**H2. The negative financial effect of the Corona crisis is less for companies in the Food & Retail industry**

In Table 6, the results of the abnormal returns for the industry subsamples are presented when employing the market model for the 20-day event period. The mean cumulative abnormal return for Manufacturing is -37.16%, for Transport & Logistics is -33.22%, for Automotive is -45.38% and for Food & Retail is -21.07%, all significant at the 1% level. This indicates that the Corona crisis had a negative effect on the sample firms in each industry separately. The mean CAR for firms in the Food & Retail industry seems to be much less negative than for firms in the other industries, as hypothesized. To compare the mean CAR for firms in the Food & Retail industry with the mean CARs for firms in the other three industries, two-sample t-tests are employed to obtain t-statistics for differences in means. As can be seen in Table 6, all the differences in means are statistically significant. The negative cumulative abnormal return for firms in the Food & Retail industry is thus significantly less than the negative cumulative abnormal returns for firms in the other three industries, supporting hypothesis H2. For completeness, the mean CARs from the Manufacturing industry, the Transport & Logistics industry and the Automotive industry are also compared with each other to check whether there is a statistically significant difference in means. None of these differences in means are statistically significant. The difference between Transport & Logistics and Automotive is rather large (12.16%) and therefore a statistically significant difference would not have been unexpected, but the two-sample t-test indicates that it is not significant at the 5% level. A possible reason can be the small sample sizes for the two industries.

Table 6: Comparison of Cumulative Abnormal Returns using the market model for Days (0,19) for the industry subsamples versus the Food & Retail industry

<table>
<thead>
<tr>
<th>Market model for each industry</th>
<th>Difference to Food &amp; Retail industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>Mean</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>32</td>
</tr>
<tr>
<td>Transport &amp; Logistics</td>
<td>12</td>
</tr>
<tr>
<td>Automotive</td>
<td>12</td>
</tr>
<tr>
<td>Food &amp; Retail</td>
<td>33</td>
</tr>
</tbody>
</table>

Tests are two-tailed: *p<0.05; **p<0.01

14
All in all, it can be concluded that the Corona crisis had a negative effect on the financial performance of companies. Firms lost on average 31.77% of their shareholder value as a result of the Corona crisis during the one-month period after the first containment measures in Europe. A comparison between the four different industries indicated that the negative financial impact of the Corona crisis was less for companies in the Food & Retail industry.
5. Results of the case studies

5.1 Lessons learned

In this section, the lessons learned derived from the interviews are presented for each company.

Company A

Company A is a logistic service provider. They make use of a light-asset strategy, which allows them to provide customized solutions to a large number of companies. They can offer end-to-end solutions or only (partial) warehousing to their customers. Company A identifies five markets in which they operate marketing wise, namely industrial, consumer products, high-tech, automotive and healthcare. However, they have customers in all types of markets. Their business consists of 70% distributor of retail (B2B), 20% industrial and 10% e-commerce. Due to the Corona crisis, they expect the e-commerce business to increase. Since Company A is a logistic service provider, they do not have suppliers that deliver products to them. Their suppliers are mainly transportation companies/agencies, large integrators such as UPS and DHL, and labour agencies.

Lessons learned Company A

The business model of Company A focuses on flexibility and working hands-on. This makes it easy to scale up and scale down in different situations which indicates that they can be efficient when it comes to capacity. Namely, they do not have surplus capacity, however, because of their flexibility, they can easily acquire it when it is needed. During the Corona crisis, it was needed to lay-off a lot of flex workers to decrease their costs. Because of the flexibility in the business model, it did not result in any issues. Besides this, Company A works with sub-contracts which make it easy to distance themselves from suppliers and assets (such as equipment and warehouses), but they can also easily attract new suppliers and assets if necessary. This results in less dependency on their supply chain partners. All of these elements have a positive impact on the resilience of Company A. However, sometimes the company sticks too much to the business model and does not pay enough attention to the human side. The scaling down of suppliers could lead to future partnership problems, because the suppliers lost trust in Company A and might not want to work with them anymore.

The financial position of Company A is relatively strong. Their revenue decreased due to the Corona crisis, but the profit still increased due to lower costs and a high efficiency of staff deployment. However, during the crisis, there was also an increase in certain costs. The main reasons for this are the Corona measurements, scarceness of air and ocean freight capacity, a higher illness rate and a lower productivity. During the Corona crisis, there was more in-depth monitoring to check the credit position of customers and suppliers which may influence their supplier selection in the future. Also, customers were more willing to give insights into their data which increased the visibility in the chain. Furthermore, during the crisis, Company A did not buy own shares to be able to use this cash instead for other activities. A positive aspect of the Corona crisis for Company A is that a lot of companies are in a weak position now. Company A has the financial assets to be able to takeover these companies. Furthermore, some competitors were struggling during the Corona crisis which led to a higher demand of their current customers and even to additional customers. The financial stability of Company A during times of crisis is an indicator of their robustness.

In the beginning of the outbreak of COVID-19, Company A made a contingency plan in no more than three weeks. This agile response to the situation had a positive impact on their resilience and helped them to get out of the crisis relatively well. Besides that, the plan accelerated decisions about actions that were already planned before Corona and it contributes to the preparation for a possibly second
wave. Company A shared a lot of information with its employees and involved them well in the actions that needed to be taken based on this contingency plan. It is worth mentioning that the loyalty and team spirit between colleagues is increased due to the Corona crisis. Furthermore, it was noticed that more initiative was taken by employees that did not do this before. There were almost no problems regarding working from home for the personnel or the digital systems in place. However, working from home did result in longer and more focussed meetings, and less 'informal' and social contact. Also, meetings with customers cannot be done physically anymore, which can be operationally challenging. The new flexible working is socially accepted by the employees and so far, Company A has not noticed any employees with burnouts or psychological issues due to the new situation. Nonetheless, they expect this to increase in the (near) future. Concerning the hiring procedures, they noticed that it is difficult to find new employees because there is a shortage on labour due to the crisis. If they eventually find new employees, the training takes longer and is less smooth due to restrictions of group sizes.

Company A is dependent on integrators such as UPS and PostNL. During the Corona crisis, the warehouses of these integrators were overloaded and they did not come to pick-up packages anymore in the warehouses of Company A. This dependability resulted in issues during the Corona crisis. Not only the integrators had warehousing issues, also the picking and packing in Company A's warehouses is more difficult due to the 1.5-meter society. This leads to a decrease in operational productivity. All in all, despite some issues, Company A got through the crisis relatively well. They might even have come out of the crisis better than before the crisis happened.

**Company B**

Company B is a high-tech company in the Semicon industry. The Sourcing & Supply chain department of Company B manages over 100 chains up to seven tiers deep, addressing potential bottlenecks and supply risks before they impact their customers. Since they have so many suppliers, it is infeasible to manage all suppliers. Therefore, their first-tier suppliers play an important role to create visibility in the supply chain and prevent stops for Company B.

**Lessons learned Company B**

One of the most important lessons learned about how Company B reacted to the Corona crisis, is their flexibility. From the literature summary in section 2, it can be concluded that flexibility is an important element of successful resilience. Company B has knowledgeable and multidisciplinary teams and is therefore flexible in changing the sequence in the production of machines by dynamic planning. Also, they have a high flexibility in the use of parts. They can use one part to test multiple machines, implying that the production does not come to a stop. Another way that Company B used to keep the production running is the usage of spare parts for the production of new machines. This was useful to minimize the impact of the disruption.

During the crisis, Company B started to collect qualitative information at suppliers to deep dive into causes of issues at the supply side. Company B has many different suppliers. Most of the components that they use in their machines are single sourced. This strategy is inevitable because of the complexity of the delivered components. However, single sourcing is a risk for Company B during disruptions, since they are very dependent on individual suppliers who are the only ones that can produce these components. This makes it expensive to switch suppliers when they are facing supply issues. Furthermore, there was reduced interaction with suppliers about strategic decisions because physical meetings were not possible due to the working from home. On the other hand, there was
more digital daily contact concerning operational decisions. An aspect that Company B encountered, is that they could have been faster in taking their role in helping their suppliers to make clear to the governments that their business is critical, since some of their suppliers were struggling with getting clearance for their products. Company B prepares for a future disruption by investigating on how certain suppliers reacted to the current crisis, and if they will be able to prepare better for a new disruption.

Company B is primarily dependent on one transport modality: air. The dependability on one transport modality makes the company less flexible, because they cannot easily switch between transport modalities. This has a negative impact on resilience and robustness. During the Corona pandemic, the availability of belly freight heavily decreased, which led to higher transportation costs and impacted their spare parts operations. This resulted in an increased lead time in delivering spare parts at customers sites, which is very expensive. Additionally, shifts were adapted in the factory operations. Less employees were allowed to be in the Clean Room due to the Corona restrictions and there was more time between the shifts to change the workforce.

In June 2020, the supply chain of Company B was recovered from the Corona crisis, which indicates a high level of resilience. This recovery was accelerated by the volume drop in the Automotive industry. Because of this drop, the suppliers of Company B, that normally also deliver to Automotive, could now focus more on delivering supplies to Company B. However, it is uncertain what the supply effects will be when the Automotive or other industries recover again. For certain suppliers, Company B is only a small player and these suppliers could prioritize other customers.

**Company C**

Company C creates unconventional logistics products for their customers and industry. They develop intelligent systems and processes, which they continuously innovate to stay ahead of the curve and solve the latest challenges in logistics. Innovation through co-creation is part of Company C’s DNA. The standard was set with the introduction of the Mega trailer into the European transport market in 1990. This has been followed by further developments, making it suitable for multi-modal purposes and being more eco-friendly.

Full loads or part loads, business as usual or unique project-based requests, within or outside of Europe, Control Tower set-ups and Value-Added Logistics; by combining multiple products of its portfolio, Company C provides solutions that enable the development and optimization of supply chains.

This research focuses on the business unit (part of Company C) that specialises in Control Tower products: Company Ca. The most substantial end market of both Company C and Company Ca is the Automotive industry. Besides Automotive, Company Ca is also active in the transportation of paper & packaging and food & beverage.

Company Ca helps their customers to manage their logistics processes while creating visibility and control as well as transparency for them. To enable this, Company Ca performs the following activities as a single point of contact: executing and optimising (inbound/outbound) transports, invoicing/self-billing, continuous improvement, follow-up on the performance of carriers and providing reports and business intelligence. Besides this, they can also provide logistics consultancy like network optimisation exercises, tendering and procurement.
**Lessons learned Company C & Company Ca**

Company C works from a ‘family spirit’. This means that suppliers are not easily discontracted, which leads to loyalty and good partnership. However, this is also a risk, because it results in being less flexible in times of crisis.

Working from home resulted in almost no problems for the personnel or digital systems in place. However, working from home did result in longer and more focussed meetings, and less ‘informal’ and social contact. There was no/few absenteeism due to illness and no forced layoffs, but there was a stop on hiring new employees. During the Corona crisis, there was a very good internal communication; employees knew what was happening in the company and what was expected from them. This can be attributed to the fact that Company Ca is a relatively small organisation with short communication lines and fast handling of issues. A positive aspect was that suddenly, due to the crisis, good collaboration and cooperation within the internal network was possible, where it was difficult before the crisis. To deal with the main issues related to the crisis, a Corona team was set up. The agile reaction in setting up a Corona team positively impacts their resilience. On the other hand, Company C does not have a plan to prepare themselves for a second wave (as far as they were aware). They indicate that the future is so uncertain that it is not valuable to put effort in creating a plan now. Contradictingly, the interviewees mentioned that maybe the Corona team is working on a plan, but the interviewees were not aware of this. So, it is not always clear what the Corona team is working on; this indicates a lack of transparency within the company.

Company C is very dependent on the Automotive industry. This dependability makes the company less flexible which has a negative impact on resilience and robustness. During the economic crisis in 2008, they already noticed that the Automotive industry is vulnerable, so they should move their focus away from this market to have a more diversified customer portfolio. However, since the Automotive industry is a very profitable market, and switching to a new market is accompanied with lower margins to attract new customers, this is rather difficult for them. The Corona crisis again showed that the Automotive industry is vulnerable; there was a big drop in volumes. Because of this drop, there is an overcapacity in the transportation sector, which leads to price wars. It is the question whether the volumes will recover at all, and how long it will take. This is a big risk for Company C, but they have scenarios in place for when the automotive volumes remain low.

In general, there is minimal visibility and transparency in the supply chain. This works both ways; on the one hand, there is only limited information received from the customers. On the other hand, especially during the crisis, Company C was not sharing much information with external partners. This lack of visibility and transparency in the supply chain is one thing that should be improved for the future. Since the crisis, customers ask for more track and trace; this is an opportunity for Company Ca to provide more supply chain visibility to their customers. Additionally, customers are willing to share more information, because they also see the importance of sharing information due to the Corona crisis.

During the Corona crisis, the revenue of Company Ca highly decreased. However, the margins decreased at a slower pace than the revenue because of governmental support for personnel costs, fixed fee agreements with customers and a decrease in the fuel rates. Another financial impact of the Corona crisis is that the insurance companies have lowered the credit coverage, which resulted in Company C lowering the number of outstanding receivables per customer. A positive aspect of the
crisis is that Company Ca noticed that customers are extending contracts, because they are not focused on tendering now; their priorities are at other decisions.

The influence of the ‘lack of’ policies made by the EU is big; the EU does not have a clear policy for all its members, but it lets each country decide upon their own rules concerning the closing of borders, the wearing of face masks etc. For Company Ca, this was a big issue, because their trucks and drivers often need to cross different countries to get to the final destination.

Because of the crisis, they realised even more that their information system was outdated and inflexible. They also indicate that people are their strongest resource. A system should operate autonomously, but in the current situation, people are required to let the system run smoothly. They plan on accelerating the process of renewing their IT systems, because they are now not agile enough in seizing the growing digitalisation opportunity.

All in all, even though their biggest market (Automotive) was impacted severely, Company C only needed to take limited actions to mitigate the impact of the Corona crisis.

Company D
Company D is a company that designs and manufactures electronics for various sectors. The main market sectors they supply to are Automotive, Medical, Defence, Industrial and Semiconductor. As a supplier to the Semiconductor sector, they are a supplier of Company B. Besides Company B, Company D has many customers all over the world. Most of the time, they are the 1st or 2nd tier supplier for these customers. The operations of Company D cover the full lifecycle management of professional electronics in the business to business segment: from the initial idea to development and production, and also the repair and service. In close cooperation with their customers, Company D offers customised solutions for high-end electronic applications. They have factories in the Netherlands, Germany, Czech Republic, Slovakia, China and the United States. Company D is a company high upstream in the supply chain and has a couple of thousand suppliers all over the world.

Lessons learned Company D
This research concentrates on the department of Company D that has its main focus on Healthcare and Semicon. These two markets are very stable markets, also during the Corona crisis. For the future, they expect that Healthcare will remain stable and that Semicon will be a stable growing market. However, there is still uncertainty about whether the Semicon industry will be as highly impacted as during the economic crisis in 2008.

Company D is dependent on airfreight. During Corona, the availability of belly freight heavily decreased, which led to delays of shipments and higher transportation costs. The dependability on one transport modality makes the company less flexible which has a negative impact on resilience and robustness.

A risk for Company D is the usage of single sourcing for their components. They are very dependent on certain suppliers because these are the only ones that can make certain components. This makes it hard to switch suppliers when they are facing supply issues. However, there is an interdependency in the whole network, so the customers of Company D are also very dependent on them. This leads to a partnership atmosphere amongst suppliers and customers in the supply chain network which results in good collaboration. An example of this collaboration is that during the Corona crisis,
Company D helped suppliers by paying them earlier when they asked for it. Additionally, suppliers indicated that there was a need for extended forecasts, which were given to them by Company D to obtain more insights. Another aspect that happened during the crisis, is that there has been less turbulence in the supply chain due to suppliers and customers focusing on own operations instead of interfering with other supply chain partners. What also became evident during the Corona crisis, is that in some cases the supplier risk assessments and the criticality levels of certain components are not accurate enough. The reliability of suppliers dropped from 90% to 70%. Therefore, Company D is now profiling their suppliers that are dependent on other (highly impacted) industries, such as the Automotive industry. In the future, this could have an impact on their supplier selection.

Company D has buffer inventories and slack time built in to the supply chain at both supply and demand side. They are also flexible in their production sequence, partly because they have short set-up times on their machines. This was convenient during the Corona crisis to keep the supply chain up and running, and it was a major reason for the fast recovery. So, Company D has seen a V-shape in their inventory levels and related KPI’s, indicating a high level of resilience.

There was a high illness rate due to Corona with accompanying higher expenses, but this did not affect the output of the company which shows their robustness. Despite pulling apart shifts because of Corona measurements which inhibits the physical handover between shifts, the productivity and efficiency in the factory even went up. This is due to less disturbance of staff employees and highly motivated personnel.

Before the Corona crisis, there was a business continuity plan in place for crisis situations. This plan was suitable for the current disruption and the strongest aspect was the clear governance structure, which made it clear for employees who to contact and what to do when problems occurred. Furthermore, because of the business continuity plan, the insurance fees that Company D has to pay are less. In the future, the business continuity plan can again be used. Also, Company D will be Corona-ready at the office and factory for a second wave because of the measures that are already taken; they made walking routes in the production site, and the desks are at 1.5 metres distance from each other. On the downside, it seemed that the hierarchical lines became more important and that the informal line and initiative taken by employees became less during the Corona crisis.

There were almost no difficulties with working from home; the digital systems of Company D were suitable for this purpose. However, working from home did result in less ‘informal’ and social contact, which might lead to a reduction of new ideas. In addition, the training of personnel became more difficult and meetings with customers could not be done physically anymore, which can be operationally challenging and can possibly lead to a decreased level of collaboration. Company D is not able to facilitate 100% of the staff at the office anymore due to the earlier mentioned Corona measures. Therefore, they have adopted a combination of working from home and working in office. As a consequence of the forced working from home, employees are more positive regarding the possibilities of working from home. An issue that may arise in the current situation, is whether the company should pay for home working office supplies (like chairs, second screens etc.) or not.

A positive aspect of the Corona crisis, mentioned by the interviewee, is that people are less likely to switch jobs in crisis situations, which results in more certainty in their work force. Also, people seem to be less likely to report sick when working from home. Furthermore, Company D was able to improve their cash flow during the difficult months, because they could make use of the
postponement of tax payments given by the government. All in all, despite some issues, Company D got through the crisis relatively well.

5.2 Survey
As described in the methodology section, a survey was made and sent out to members of the European Supply Chain Forum. In this survey, general questions were asked first to provide information about the type of company and the overall impact of COVID-19. Thereafter, questions regarding the operations of the company were included, like questions about demand, supply and production levels but also about strategies. Then, financial related questions were asked, for example about the monitoring of financial parameters. In the end, questions about collaboration, information sharing, working from home, employee well-being and hiring procedures were enclosed.

There were 10 companies that completed the survey (response rate of 18.2%), of which 60% are active in the manufacturing industry and 20% of the companies are logistic service providers. In total, 80% of the companies that filled out the survey are large companies, which implies that they have more than 250 employees. The results showed that 50% of the companies are hard or severely affected by COVID-19, as can be seen in Figure 3.

Figure 3: Survey question “How has your company been affected by COVID-19?”

Overall, the results of the survey support the results of the interviews with the DASCOVIMI consortium companies. A majority of the companies that have a production process indicated that there was a decrease in production levels during the Corona pandemic, which was not encountered by the two manufacturing companies that have been interviewed. Also, it came forward that the majority of the companies have multiple strategies in place for when a disruption happens, while only two of the four interviewed companies had a contingency plan in place before the disruption happened. Besides those two results, there are no other remarkable new insights from the survey. Therefore, the CE diagram that is created and described in the next section provides a complete overview of what happened during the Corona Crisis, based on the interviews and survey. A detailed description of the results of the survey can be found in Appendix D.

5.3 Explanation and descriptive data analysis generic CE diagram
Based on the four individual CE diagrams presented in Appendix C and complemented with the survey results, one generic cause-effect diagram is created and further explained below. The generic cause-effect diagram is shown in Figure 4 on the next page. This CE diagram provides a generic diagnosis of problems and their causes that companies can experience during pandemics and other major disruptions. The elements of the generic CE diagram are individually described in this section. Additionally, it is explained how a qualitative and/or quantitative analysis can be performed for each element and where the necessary information can be retrieved. It should be noted that for a proper analysis of the impact of a disruption, quarterly reported data or data from smaller time periods (e.g. monthly or weekly) are needed; in (semi-) annual data, the effects will probably not be visible. If the required quantitative data was made available by the DASCOVIMI companies, an example of the data analysis during the Corona crisis is provided. An overview of all this information is provided upfront in Table 7 below the figure of the generic CE diagram (Figure 4).
Figure 4: Generic Cause-effect diagram
<table>
<thead>
<tr>
<th>No</th>
<th>Element name</th>
<th>Content of the element</th>
<th>Measure</th>
<th>Where/how to find information?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Profit margin</td>
<td>• Gross profit margin&lt;br&gt;• Operating profit margin&lt;br&gt;• Net profit margin</td>
<td>Quantitative</td>
<td>Income statement or profit &amp; loss statement</td>
</tr>
<tr>
<td>2</td>
<td>Revenue</td>
<td>• Revenue</td>
<td>Quantitative</td>
<td>Income statement or profit &amp; loss statement</td>
</tr>
<tr>
<td>3</td>
<td>Cost of operations</td>
<td>• All types of costs a company can face</td>
<td>Quantitative</td>
<td>Income statement or profit &amp; loss statement</td>
</tr>
<tr>
<td>4</td>
<td>Fixed assets structure</td>
<td>• Fixed assets or non-current assets</td>
<td>Quantitative</td>
<td>Balance sheet or statement of financial position&lt;br&gt;Interview questions&lt;br&gt;Survey</td>
</tr>
<tr>
<td>5</td>
<td>Fixed personnel structure</td>
<td>• Percentage of employment contracts that cannot be terminated in the short term</td>
<td>Quantitative</td>
<td>Human resource department</td>
</tr>
<tr>
<td>6</td>
<td>Quality of operations</td>
<td>• Planning and management of operations&lt;br&gt;• Demand and supply match&lt;br&gt;• Planning of employees&lt;br&gt;• Material planning&lt;br&gt;• Flexibility in times of disruption&lt;br&gt;• Contingency plan for emergency</td>
<td>Qualitative</td>
<td>Demand levels&lt;br&gt;Supply levels&lt;br&gt;Previous forecasts&lt;br&gt;Interview questions&lt;br&gt;Survey</td>
</tr>
<tr>
<td>7</td>
<td>Reliability in operations</td>
<td>• Actual vs planned supply levels&lt;br&gt;• Actual vs planned demand levels</td>
<td>Quantitative</td>
<td>Forecast supply&lt;br&gt;Forecast demand</td>
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<td>Actual vs planned inventory levels&lt;br&gt;Output operations&lt;br&gt;Compliance to plans that are made in operations management&lt;br&gt;On time delivery (Lead time)&lt;br&gt;Rescheduling of operations</td>
<td>Actual supply levels&lt;br&gt;Actual demand levels&lt;br&gt;Inventory levels&lt;br&gt;Production(planning) data</td>
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</tr>
<tr>
<td>8</td>
<td>Training of personnel</td>
<td>Ability and ease with which new and current employees can be trained</td>
<td>Qualitative&lt;br&gt;Interview questions&lt;br&gt;Survey</td>
<td></td>
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<tr>
<td>9</td>
<td>Delay in supply</td>
<td>On time delivery of supply</td>
<td>Quantitative&lt;br&gt;On time in full (OTIF) data&lt;br&gt;Conversations with suppliers&lt;br&gt;Qualitative</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>ICT preparedness</td>
<td>ICT systems in place (e.g. Teams or VPN servers)&lt;br&gt;Planning systems in place (e.g. ERP or SAP)&lt;br&gt;Data (sharing) capabilities&lt;br&gt;Performance dashboards</td>
<td>Qualitative&lt;br&gt;Interview questions&lt;br&gt;Survey&lt;br&gt;ICT department</td>
<td></td>
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<tr>
<td>11</td>
<td>Complexity in processes</td>
<td>Internal and external processes&lt;br&gt;Number of steps in the processes&lt;br&gt;Number of resources and materials needed in the process&lt;br&gt;Number of supply chain partners involved in the process&lt;br&gt;Number and complexity of different products</td>
<td>Quantitative&lt;br&gt;BOP&lt;br&gt;BOM&lt;br&gt;Interview questions&lt;br&gt;Qualitative&lt;br&gt;Survey</td>
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<td>12</td>
<td>Demand volume</td>
<td>Demand levels</td>
<td>Demand levels&lt;br&gt;Order data&lt;br&gt;Quantitative</td>
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25
<table>
<thead>
<tr>
<th></th>
<th>Demand uncertainty</th>
<th></th>
<th>Activity in impacted market sector(s)</th>
<th></th>
<th>Customer collaboration</th>
<th></th>
<th>Consumer trust</th>
<th></th>
<th>Consumer income</th>
<th></th>
<th>Working from home</th>
<th></th>
<th>Pandemic restrictions</th>
<th></th>
<th>Dependency on impacted modality</th>
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<tbody>
<tr>
<td>13</td>
<td>Demand uncertainty</td>
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<td>Uncertainty about demand</td>
<td></td>
<td>Qualitative</td>
<td></td>
<td>Interview question</td>
<td></td>
<td>Survey</td>
<td></td>
<td>Number of industries/sectors in which company is active</td>
<td></td>
<td>Containment measures taken by government</td>
<td></td>
<td>Dependency on certain modality: road, air, sea, rail, pipeline</td>
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<td></td>
<td>Amount of impacted industries</td>
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<tr>
<td>14</td>
<td>Activity in impacted market sector(s)</td>
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<td>Number of industries/sectors in which company is active</td>
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<td>Annual report</td>
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<td>Quantitative</td>
<td></td>
<td>Sources that publish statistical information about a country, like Centraal Bureau voor de Statistiek (CBS)</td>
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<td>Amount of impacted industries</td>
<td>Qualitative</td>
<td>Interview questions</td>
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<td>Quantitative</td>
<td></td>
<td>Sources that publish statistical information about a country, like CBS</td>
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<tr>
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<td>Customer collaboration</td>
<td></td>
<td>Information shared by company with customers</td>
<td>Qualitative</td>
<td>Interview questions</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>Information shared by customers with company</td>
<td></td>
<td>Interview questions</td>
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<tr>
<td>16</td>
<td>Consumer trust</td>
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<td>Consumer's trust in economy</td>
<td>Qualitative</td>
<td>Interview questions</td>
<td></td>
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<td></td>
<td>Consumer's willingness to spend money</td>
<td></td>
<td>Survey</td>
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<tr>
<td>17</td>
<td>Consumer income</td>
<td></td>
<td>Consumer's ability to spend money</td>
<td>Qualitative</td>
<td>Sources that publish statistical information about a country, like CBS</td>
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<tr>
<td>18</td>
<td>Working from home</td>
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<td>Ability to work from home</td>
<td>Qualitative</td>
<td>Interview questions</td>
<td></td>
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<td>Effects of working from home</td>
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<td>Survey</td>
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<td>Qualitative</td>
<td>Survey</td>
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<td>Number or percentage of workforce that is/has been working from home</td>
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<td>Dependency on impacted modality</td>
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<td>Dependency on certain modality: road, air, sea, rail, pipeline</td>
<td>Qualitative</td>
<td>Annual report</td>
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</tbody>
</table>
| 21 | Single sourcing from impacted supplier | • Dependency on supplier(s)  
• Number of suppliers per material/product/component | • Qualitative  
• Quantitative | • Interview questions  
• Survey  
• Supply data |
| 22 | Supplier collaboration | • Information shared by company with suppliers  
• Information shared by suppliers with company | • Qualitative | • Interview questions  
• Survey |
| 23 | Human output | • Total amount of acceptable output during a period of time that can be achieved by the employees that perform a certain operation | • Quantitative | • Department in which the operations are performed |
| 24 | Number of people at workplace | • The number of employees that fit and are present at a workstation/workplace | • Quantitative | • Operations manager  
• Manager of production division |
| 25 | Illness percentage | • Proportion of employees of a company that are reported sick and that are unable to perform their work for a certain period of time | • Quantitative | • Human resource department |
| 26 | Pandemic occurrence | • Root cause of all issues | - | - |

An extensive explanation of all the elements in the generic CE diagram and the possible qualitative and/or quantitative data analyses for each element will be described below.
Profit margin (1)
The end effect in the CE-diagram is a change in profit margin. A company performs activities with the goal to generate profits. Profit margin is a measure of a company’s profitability and performance. It represents the proportion of sales that has turned into profits (Brealey, Myers & Allen, 2017). The profit margin of a company can be analysed quantitatively and there are three common types of profit margin:

- Gross profit margin. This can be calculated by dividing the gross profit by the net sales (or revenue). Gross profit can be found by subtracting the costs of goods sold (COGS), also known as cost of sales, or the direct costs from the net sales (or revenue).

\[
\text{Gross profit margin} = \frac{\text{Gross profit}}{\text{Net sales (or Revenue)}} = \frac{\text{Net sales (or Revenue)} - \text{COGS (or direct costs)}}{\text{Net sales (or Revenue)}}
\]

- Operating profit margin. This can be calculated by dividing the operating income by the net sales (or revenue). Operating income, also known as earnings before interest and taxes (EBIT), can be found by subtracting operating expenses, like selling, general and administrative costs, from the company’s gross profit.

\[
\text{Operating profit margin} = \frac{\text{Operating income (or EBIT)}}{\text{Net sales (or Revenue)}} = \frac{\text{Gross profit} - \text{Operating expenses}}{\text{Net sales (or Revenue)}}
\]

- Net profit margin, the most commonly used profit margin. This can be calculated by dividing the net profit by the net sales (or revenue). Net sales can be found by subtracting all associated expenses from the net sales (or revenue).

\[
\text{Net profit margin} = \frac{\text{Net profit}}{\text{Net sales (or Revenue)}} = \frac{\text{Net sales (or Revenue)} - \text{expenses}}{\text{Net sales (or Revenue)}}
\]

To analyse these different quantitative measures, a company’s income statement (or profit & loss statement) should be consulted. Depending on the reporting timeframe, the required financial numbers to calculate the profit margins are reflected on the income statement at a certain frequency (like quarterly or annually). After calculating the desired profit margin (per period), it can be used to evaluate the performance of a company over time or compare its performance against other companies in the same market.

Data analysis DASCOVIMI companies
In Figure 5 below, the three different profit margins over time can be found for Company B. These profit margins are calculated based on Company B’s income statement. As can be seen, there was a drop in all three profit margins in Q1 2019 and Q1 2020, with a bigger drop for both the operating profit margin and the net profit margin. In Q1 2019, Company B experienced a drop in profit margins which was the result of a big fire at one of their major suppliers. After that quarter, the profit margins started to show a rising pattern until the Corona pandemic occurred in Q1 2020. Because of the Corona pandemic occurrence and related governmental measurements/restrictions, several systems that were ready to be shipped and installed at customers in Q1 2020, could not be delivered and installed. The delivery and installation of these finished systems was pushed to Q2 2020, and with that the earnings that would have been received in Q1. This resulted in a drop of profit margins in Q1 2020. It can be seen that the profit margins are already recovering in Q2 2020.
The same analysis is also done for Company A. Based on Company A’s income statement, the profit margins are calculated. In Figure 6 below, the three different profit margins over time can be found for Company A. During the interview with Company A, it was mentioned that they did not see a drop in their profit margins during the Corona pandemic and even saw an increase. This can indeed be seen when looking at the three different profit margins in Q1 2020 and Q2 2020.

**Revenue (2)**

During a particular period, a company generates revenue (also referred to as sales or turnover). Revenue is a measure of the inflow of economic benefits arising from the normal operations of a company (Atrill & McLaney, 2016). Examples of these normal operations are the sales of goods or services. A company’s revenue is usually expressed as an amount earned during a period of time in a certain monetary unit.

Like the profit margin, a company’s income statement (or profit & loss statement) should be consulted to analyse this quantitative measure. Depending on the reporting timeframe, the revenue (or sales or turnover) amount can be directly found in the income statement at a certain frequency (like quarterly or annually). Based on the amounts (per period), changes in the revenue over time can be evaluated.
Data analysis DASCOVIMI companies
When looking at the revenue of Company B over time (Figure 7), it can be seen that the revenue made a big drop during the Corona pandemic occurrence in Q1 2020. This drop in revenue can be explained by the same reason that is described above for the drop in profit margins in Q1 2020; delivery and installation of several finished systems to customers were delayed to Q2 2020 because of the Corona related governmental measurements, which resulted in a delay of receiving income. Of course, revenue and profit margins are related concepts, and the drop in revenue is (part of) the reason for the drop in profit margins in Q1 2020.

![Company B Revenue](image)

*Figure 7: Company B Revenue over time*

Figure 8 below shows the revenue of Company A over time. It can be seen that Company A only experienced a small revenue drop when the Corona pandemic occurred in Q1 2020. This small drop in revenue is part of the reason for the stability and increase in profit margins in Q1 and Q2 2020 that is described above.

![Company A Revenue](image)

*Figure 8: Company A Revenue over time*

Costs of operations (3)
In the process of generating income, a company incurs costs (or expenses). Costs is a measure of the outflow of economic benefits arising from the normal operations of a company (Atrill & McLaney, 2016). A cost is usually expressed as an amount spend during a period of time in a certain monetary unit. There are many types of costs that can be incurred, for example cost of goods sold, salaries and wages or interest. The element Costs of operations comprises all different types of costs that a company can face.

Like the profit margin and revenue, a company’s income statement (or profit & loss statement) should be consulted to analyse this quantitative measure. Depending on the reporting timeframe, the different costs can be directly found on the income statement at a certain frequency (like
quarterly or annually). Based on the amounts on the income statement, it is possible to evaluate changes over time both of the total costs of operations and of the different types of costs, together with changes in the composition of the total costs of operations.

Data analysis DASCOVIMI companies
Based on the income statement of Company B, the total costs of operations are calculated. In Figure 9, it can be seen how these total costs of operations change over time. Just like the revenue, there was a big drop in total costs of operations in Q1 2020 during the occurrence of the Corona pandemic. In Figure 10, the total costs of operations are broken down into the different cost types. It can be derived that the drop in total costs of operations in Q1 2020 is mainly caused by a drop in total costs of sales. The other types of costs remained roughly the same compared to the quarter before and the quarter after Q1 2020. When there is a drop in revenue, it is expected that the total costs of sales will also be lower, because the total costs of sales are related to the revenue that is generated in a period. Therefore, it can be deduced that Company B did not encounter any major changes in its costs because of the Corona Pandemic.

Figure 9: Company B Total costs of operations over time

Figure 10: Company B Composition of total costs of operations over time
The total costs of operations are also analysed for Company A, based on its income statement. In Figure 11 below, it can be seen how these total costs of operations change over time. It is comparable to the pattern of the revenue, with a small drop in total costs of operations in Q1 2020 during the occurrence of the Corona pandemic. In Figure 12, the total costs of operations are broken down into the different cost types. It can be derived that the drop in total costs of operations in Q1 2020 is mainly caused by a drop in direct costs, which is an equivalent for costs of sales, and which includes staff costs of flex workers. The other types of costs remained roughly the same compared to the quarter before and the quarter after Q1 2020. As described above, it is expected to see a drop in direct costs when there is a drop in revenue. Furthermore, during the interview it was indicated that they laid-off a lot of flex workers to reduce costs. Therefore, it can be deduced that Company A did not encounter any major (unexpected) changes in its costs because of the Corona Pandemic.

**Figure 11: Company A Total costs of operations over time**

**Figure 12: Company A Composition of total costs of operations over time**

**Fixed assets structure (4)**

Fixed assets, also called non-current assets, are assets that are not held for the short term but are held for long-term operations (Atrill & McLaney, 2016). For example, property, plant and equipment is a well-known fixed asset. These fixed assets are expressed as monetary value in a certain monetary unit.
The element *Fixed assets structure* can be analysed quantitatively and qualitatively. Quantitative information regarding fixed assets can be found on a company’s balance sheet, also known as the statement of financial position. The total fixed assets and its composition can be evaluated over time. It is also possible to evaluate the different types of fixed assets individually over time. Whether a company has a lot of fixed assets or almost none, is a decision that is dependent on the company’s strategy. This strategic decision can be evaluated qualitatively, for example through related questions in an interview or a survey. The strategic decisions regarding a company’s fixed assets structure can also be compared with the strategies from competitors.

**Data analysis DASCOVIMI companies**

In Figure 13 below, Company B’s total fixed assets over time can be found. These total fixed assets for each quarter are found on Company B’s balance sheet. It can be seen that there is an overall increasing pattern in the total fixed assets over time, also in Q1 2020 and Q2 2020 which is during the Corona crisis. To see how the different types of fixed assets caused a change in the total fixed assets, the composition of the total fixed assets over time is displayed in Figure 14. It can be derived that the increase in total fixed assets during the Corona crisis (Q1 and Q2 2020), is mainly caused by an increase in Property, plant and equipment, an increase in Finance receivables and an increase in Right-of-use assets - Finance. The other types of fixed assets remained almost the same. Also in the quarters before the Corona pandemic, the increase in total fixed assets was mainly attributed to an increase in Property, plant and equipment, Finance receivables and Right-of-use assets – Finance.

![Company B Total fixed assets over time](image1)

*Figure 13: Company B Total fixed assets over time*

![Company B Composition of total fixed assets over time](image2)

*Figure 14: Company B Composition of total fixed assets over time*
**Consumer trust** (16)

When referring to the element *Consumer trust*, trust in the economy and the willingness to spend money are critical aspects. In literature, it can be found that consumer trust relates to the uncertain relationship between the consumer (trustor) and a supplier of a good or service (trustee). The trustor lacks control over the decisions of the trustee, which is of high importance to the trustor. Consumer trust regards the trustor’s confidence about the actions and intentions of the trustee (Jarvenpaa, Tractinsky & Vitale, 2000). The trust in economy is in line with the definition of trust described above, but it refers to a broader spectrum as it encompasses the economy as a whole. Willingness to spend money is relatively straightforward and is closely related to the trust in the economy and other external factors. It is a decision process regarding the time of acquisition and evaluates whether consumers are reluctant to spend money, impartial about spending money or postpone their spending (to necessary times).

The element *Consumer trust* can be measured both qualitatively as well as quantitatively. By asking consumers about their trust in the economy and willingness to spend money, for example in interviews or surveys, consumer trust can be assessed. In such interviews or surveys, it is also possible to inform about reasons for certain behavior and decisions. Besides qualitative analysis, consumer trust can also be analysed quantitatively. Organisations like Centraal Bureau voor de Statistiek (CBS) publish statistical information about diverse topics for the Netherlands, among which information regarding consumer trust. With this kind of information, the consumer trust of consumers in a specific country can be analysed.

**Data analysis statistical information sources**

To see how the consumer trust changed over the years and what the impact of the Coronavirus is on the consumer trust, two sources that publish statistical information are consulted. In Figure 15 below, information from CBS regarding consumer confidence in the Netherlands can be found. Note that consumer confidence is another name for consumer trust. As can be seen in the figure, the Coronavirus has had a significant negative impact on consumer trust. The consumer confidence indicator has dropped from around -2 in the first three months of 2020 to around -30 in the months afterwards.

![Figure 15: Consumer trust in the Netherlands (CBS, 2020c)](image)

Destatis, a German statistical information source, is consulted to gather information regarding the consumer trust in Europe. Figure 16 shows this consumer sentiment, another name for consumer trust, in Europe. Like the consumer trust in the Netherlands, the consumer trust was impacted severely by the Coronavirus. The consumer sentiment indicator has dropped from around -5 in the beginning of the year to around -20 since the Corona pandemic occurred.
This element encompasses consumer’s ability to spend money. The world economy has been hit hard by the Corona pandemic. Prime Minister Boris Johnson compared legislative actions and economic effects against war time in the Second World War (Sullivan, 2020). The Wall Street Journal went even further by comparing the economic effects to the great depression of the 1930’s (Zumbrun, 2020). Whether it compares to the greatest economic downturns of the past century or not, the pandemic unmistakably had a great impact on the world economy, affecting billions of people. The pandemic has forced a transition in how people work: forcing people to work in an adapted work environment, to work from home or not to work at all. Where various sectors thrived during the pandemic, some companies were forced to file for bankruptcy or had to lay off employees which implies that people lost their source of income. For self-employed individuals these times have been even more uncertain. No matter where one works, almost everyone’s work has been affected by the pandemic. Governmental aid certainly helped some companies and self-employed to keep their head above the water. However, the incomes of billions of people are affected, and with that the ability of consumers to spend money.

The element *Consumer income* can be analysed quantitively. Information and numbers about (un)employment figures and consumer spending can be retrieved from sources like CBS. This can be used to evaluate consumer’s ability to spend money and how this evolves over time.

**Data analysis statistical information sources**

To see how the consumer’s ability to spend money changed over the years and what the impact of the Coronavirus is on consumer’s ability to spend money, information regarding consumer spending and unemployment figures are retrieved from CBS. In Figure 17 below, the domestic household consumption, another name for consumer spending, in the Netherlands can be found. It can be seen that the occurrence of the Corona pandemic has had a major impact on the consumer spending. From March 2020 onwards, there is a negative change in consumer spending compared to those months last year.
In Figure 18, the unemployed labour force in the Netherlands can be found. It can be seen that the total number of people that are unemployed, and especially those that are unemployed for less than a year, have increased significantly in Q2 2020 after the Corona pandemic occurred (CBS, 2020b). The number of people that are unemployed for more than a year still decrease a little during the Corona pandemic, following the decreasing trend from the previous quarters. When more people are unemployed, it means that people have lost their jobs or could not get a job, which in turn has an effect on their ability to spend money.

Illness percentage (25)
The meaning of the element *Illness percentage* is straightforward. It refers to the proportion of employees of a company that are reported sick and that are unable to perform their work for a certain period of time. The proportion is expressed as a percentage of the total number of employees working at a company.

This element can be analysed quantitively. The illness percentage can be retrieved from the human resource department. It can be evaluated how the percentage changes over time and whether trends/patterns can be discovered. In addition, it may be possible to connect changes in this number to changes in company’s (output) performance or to events that happened at specific moments in time. Information and numbers about the total illness percentages of employees in a country can be retrieved from sources like CBS.
Data analysis statistical information sources
To see how the illness percentage among Dutch employees changed over the years and what the impact of the Coronavirus is on the illness percentage, information from CBS is consulted. During the year, the illness percentage follows a seasonal pattern that is related to the outbreak of influenza epidemics and other virus outbreaks. As can be seen in Figure 19, there was a significant higher illness percentage during the start of the Corona pandemic in Q1 2020 and Q2 2020 compared to the illness percentage in those quarters in previous years (when there was no pandemic) (CBS, 2020d).

For the six elements that are described below, no example will be given of the proposed quantitative data analysis, because the required data was not made available by the companies in the DASCOVIMI consortium or found on public sources.

Fixed personnel structure (5)
A company’s personnel structure consists of the number of employees that have certain types of employment contracts. The three most noteworthy employment contracts are: a permanent employment contract, a temporary/fixed-term employment contract and a contract with a recruitment agency (flex workers). When a company has a lot of flex workers, it is able to easily scale down on those employees when necessary. For employees with fixed-term contracts or permanent contracts, this cannot be done. Therefore, employment contracts that cannot be terminated in the short term are seen as ‘fixed’.

This Fixed personnel structure element can be analysed quantitatively. The number of employees that have a specific contract, and with that the percentage of fixed personnel, can be retrieved from the human resource department. It can be analysed how these numbers change over time and whether big changes are made regarding specific contract types.

Pandemic restrictions (19)
The occurrence of a pandemic can cost the lives of many people and could have an impact on the operations of companies. To delay the spread of the disease and reduce its impact, containment measures are normally taken by governments. The element Pandemic restrictions encompasses all measures that are taken in an attempt to contain the pandemic. Examples of such regulatory and preventive measures during the Corona pandemic are social distancing (1.5-meter society), working from home, mandatory quarantine, lockdowns, closing of borders and travel restrictions.

The Pandemic restrictions element can be assessed in a qualitative manner. Information regarding restrictions can be retrieved from publicly accessible sources of a country’s government, or news
sources. By asking questions related to those restrictions during an interview/meeting or incorporating them into a survey, insights on the restrictions’ consequences and impacts on a company can be obtained.

**Working from home (18)**
The meaning of the element *Working from home* is straightforward. Most jobs require employees to be present at a company’s location, for example a production site, to perform their tasks. However, some jobs or functions enable employees to work from home. As stated above, obligatory working from home was one of the measurements taken by governments during the Corona crisis.

The element *Working from home* can be measured both qualitatively and quantitatively. Qualitative information concerning working from home can be obtained through an interview/meeting or survey. For instance, it can be examined whether working from home is possible, what effects working from home has on employees and/or the company, or whether working from home will be accepted as ‘the new normal’ for a company. In the interview template in Appendices A and B, examples of questions that can be asked about working from home can be found. Quantitative information about working from home, like the number or percentage of the workforce that is able to work from home or that is/has been working from home, can also be analysed. These numbers can be retrieved from human resource reports or databases.

**Training of personnel (8)**
The element *Training of personnel* can be described as the ability and ease to which trainings can be given to new employees or current employees at for example the office, warehouses or production facilities. It comprises all kinds of trainings for (new) personnel, e.g. trainings to acquire skills to be able to execute work task or trainings to expand an employee’s skills.

This element can be evaluated qualitatively, for example through questions in an interview, a survey or a meeting. By informing about the existence of problems with training (new) employees, it can be determined whether it is easy or difficult to train personnel and which impact it can have on the operations of a company. In the interview template in Appendices A and B, an example question that can be asked about training of personnel can be found.

**Number of people at workplace (26)**
The meaning of the element *Number of people at the workplace* is straightforward. It refers to the number of employees that fit and are present at a workstation/workplace to perform their job. For example, assume that a certain assembly workstation can normally be occupied by 6 employees. During the Corona crisis, the government imposed social distancing restrictions and there was a higher illness percentage. Because of this, the assembly workstation was only occupied by 3 employees. It is reasonable to expect that the number of people that are present at a workplace will have an impact on the operations of a company.

The *Number of people at the workplace* element is a quantitative measure. Certain people in the company, for example an operation manager or a manager of a production division, should be able to provide such numerical information. Based on this information, it can be evaluated how the number changes over time. In addition, it may be possible to connect changes in this number to changes in company’s (output) performance or to events that happened at specific moments in time.

**Human output (23)**
The element *Human output* can be described as the output of all employees that together perform a certain operation in a company, e.g. picking products in a warehouse, assembling a machine or product, packing products for shipments etc. It regards the total amount of acceptable output during
a period of time that can be achieved by the related employees. Acceptable means that the output
does not contain defects or errors. As a fictional example, ten employees that are assembling a
product have an output of 50 products per hour. When only 5 employees are performing the same
product assembly, there is an output of 30 product per hour.

This Human output element is a quantitative measure. Information regarding the output of an
operation and the number of employees that worked on that operation can be retrieved from the
department in which the operations have been performed. It can be analysed how these outputs
change over time.

The explanations and data analyses for the elements described below (page 39-46) are written by
fellow DASCOVIMI student member Valerie Geelen.

Quality of Operations management (6)
Operations management is a very broad term, and therefore needs more explanation on how it is
used in the context of this research. Here, we interpret the operations management as the capability
of the company to create a plan that is realistic and viable, and to make sure that the operations can
be carried out according to the plan. It is mainly about the planning and management of operations,
such as the planning of employees, material planning, the choice of certain KPIs, and the forecasting
and matching of demand and supply. Besides these aspects, we also take into account the extent to
which a company is flexible in times of a disruption, i.e., to which extent and how quickly they are
able to adapt their processes to a new situation, and whether or not they have a contingency plan in
place.

Quality of operations management can be measured both qualitatively and quantitatively. The
assessment whether the company is flexible, and whether they have a contingency plan in place for
when a disruption happens can be measured qualitatively, by means of interviews. The specific
questions that are asked to the companies in the DASCOVIMI consortium can be found in Appendices
A and B. On the other hand, the demand and supply forecast should be measured quantitively. There
are different methods that can be used to make a forecast, such as moving average, weighted
moving average and exponential smoothing. Research of Samvedi, & Jain (2013) shows that the
exponential smoothing method gives better results during disruptions, and also during stable times.
To create a demand forecast using exponential smoothing, the forecast of the previous period in
combination with the current, actual observation is needed. This can be found in for example order
data.

Reliability in operations (7)
The Reliability in operations box refers to the extent to which the plans that are made in the
operations management are actually accomplished or even enhanced. For example, the forecast that
is made can be checked with the actual demand or supply that is faced. Also, it should be checked
whether the KPI levels that were set beforehand are achieved. If the desired levels are not achieved,
it is important to find out why this is the case. It should also be checked if rescheduling of the
operations is possible. This rescheduling can lead to operations being more reliable. If the desired KPI
levels (after rescheduling) are still not achieved, a root-cause analysis of the issues that arise in
operations can be useful. A root-cause analysis should encompass all problems that a company has
encountered and gives insights in what are the main bottlenecks.

The reliability in operations should be measured mainly quantitatively, based on data. This can be done
by using order/demand data, production data, inventory data, supply data, and forecast and
(production)planning data. The data can be used in many ways. One example to see what actually
happened, is to create graphs where certain data is plotted over time. The data can also be used to
create a table which indicates what you have, what you (will) get from your suppliers, and what will go out due to customer demand.

Data analysis DASCOVIMI companies

Figure 20 shows the actual demand expressed in euros that Company Ca had compared to the forecast they made. There are two forecasts to be seen in Figure 20. One forecast is made at the end of 2019, over the full year of 2020 and the other forecast is made in May 2020. During the peak period of COVID-19, in March and April, it can be seen that there was a big drop in demand which was not forecasted. This shows that the plans that were made beforehand could not be achieved during a time of pandemic. Another aspect which is interesting to look at in Figure 20, is the discrepancy between the forecast that is made in May 2020 and the forecast that is made at the end of 2019. It can be seen that overall, the forecast that is made in May is lower, which indicates that after COVID-19, Company Ca expects the demand to be lower than before, and therefore adjusted their forecast.

Figure 20: Company Ca Actual vs Forecast Demand

Another aspect that can be checked is the level of inventory. Figure 21 shows the inventory that comes in and goes out, and the inventory balance of one of the suppliers of a supplier of Company B. This table is made by Company B to see what their supplier can expect in the future, and therefore also what Company C can expect in the future. It can be seen that at the table that is made at 20/02/2020, they expected to have a negative inventory balance in week 11, 12, 13 and 14. For the same supplier, the table was also made at 26/02/2020. The green cells indicate that the goods were delivered earlier than planned. It can be seen that, because of this improved delivery date of the products, the inventory balance was only negative in week 11, so there was a big improvement compared to one week earlier.

Figure 21: Inventory balance of one of the suppliers of a supplier of Company B

Company D has made a root-cause analysis for their on-time deliveries to one of their customers. This can be seen in Figure 22. The numbers on the y-axis indicate the number of times that Company D was not able to deliver an order on time. The numbers on the x-axis indicate the week in which it happened. For example, 2019 indicates week 19 in 2020. It can be seen in Figure 22 that especially
from week 10 until week 19, the capacity constraints were rather high. Together with the material constraints, this was the highest bottleneck during this period, which was the peak of the Corona crisis. In week 12 there was a big bucket of ‘Onterecht’. This means that it was not the fault of Company D that there was a hit on the on-time delivery. The reason for these hits were problems at the integrators side. This is an interesting finding, that was also mentioned in the interviews.

**Figure 22: Root cause analysis Company D**

**Delay in supply (9)**

The box *Delay in supply* is rather self-explanatory. It concerns whether suppliers deliver their items on time or not. This should be measured both quantitively and qualitatively. First of all, in the supply data it should be checked whether the suppliers delivered the items on time, and if it is in compliance with the KPIs. The On-Time in Full (OTIF) data can be monitored (for example on a dashboard) to see the performance of the suppliers. If this performance is below the normal performance of that supplier, conversations with suppliers can be helpful to find out the reason why the items are not delivered on time by for example a root-cause analysis.

**Data analysis DASCOVIMI companies**

When looking at the monthly OTIF data of all suppliers of Company B (Figure 23), it can be seen that normally the performance is around 80%. This indicates that 80% of the time, the suppliers deliver the goods on time. It is important to note that Company B allows their suppliers to deliver either five days before the due date and three days after. When the suppliers deliver the goods within this range, this will not have a negative impact on their OTIF score. In Figure 23 it can be seen that during May 2020, which is in the Corona period, the performance of the suppliers significantly dropped to 75.7%.

**Figure 23: Monthly OTIF performance of all suppliers of Company B**
The OTIF scores can also be monitored per supplier. When zooming in on one specific supplier of Company B, more detailed information can be obtained, which makes it easier to come up with the causes for supply disruptions. Figure 24 shows the OTIF performance of one specific company. It can be seen that already in January there was a big drop in their performance. This drop was unrelated to Corona, but it did impact their performance during the Corona period. Normally they would have buffer inventory and capacity, however, because they were already compensating for the big drop in January, they were more heavily impacted due to Corona then they would have been otherwise.

For the same supplier of Company B, a root-cause analysis was performed. This showed that most of the problems were caused by material constraints and (especially during the peak of COVID-19) capacity constraints at the supplier’s side.

Figure 24: Monthly OTIF performance of one specific supplier of Company B

Company B obtains Vendor Undesired Re-Out (VURO) data of their suppliers. A company has a ‘hit’ on their VURO score if they inform Company B that the product that they are supposed to deliver, is delivered at a different moment in time. If this happens often, it has a negative impact on the reliability of that supplier. Figure 25 depicts a graphical representation of the VURO scores of one particular supplier of Company B. It can be seen that this supplier had relatively low VURO scores in 2019, indicating that it is a rather reliable supplier. However, in April 2020 there is a very high peak, which can be attributed to Corona. In the months after April 2020, it can be seen that the VURO scores are already lower, however still a lot higher than before the Corona crisis.

Figure 25: Company B VURO data of one specific supplier

**ICT preparedness (10)**

ICT preparedness includes a number of different aspects. In this research, the ICT aspects that support overall operations (also in case of disruptions) will be addressed. The first aspect that is considered, is whether a company has ICT systems in place that make the working from home
possible. Examples of this are Microsoft Teams, but also a good working VPN connection that employees can access from home. Another aspect that is part of ICT preparedness is whether the company has planning systems in place, such as ERP or SAP. When a company has these planning systems, there is more structure and clarity, and this can be an advantage in terms of reacting to a disruption. One thing that goes side by side with this, is how the data is shared with the supply chain partners. For example, can the supply chain partners access the (planning) systems of the company, or is all information shared through emails etc. The final aspect of ICT preparedness is whether the company has a dashboard to monitor relevant performance aspects. All of this information can be obtained in a qualitative manner, for example through interviews or surveys with employees from the ICT department. The specific questions about this topic that can be asked can be found in Appendices A and B.

**Complexity in processes (11)**
The complexity in processes concerns both internal and external processes. The complexity can be described as the number of steps in the processes, the number of resources and materials that are needed in the process, and the number of supply chain partners (and their location) that are involved. This can be measured quantitatively, namely the higher all these numbers, the more complex the process is. Additionally, the number of products, and the complexity of these products, that are part of a company’s portfolio also have an influence on the complexity of processes. When there are highly complex processes in a company, a clearly structured BOP (bill of processes) and BOM (bill of materials) can be useful to get insights in what actually happens in the process, and who is responsible for what. The complexity in the processes can also be measured qualitatively, by conversations with the companies involved. If they already have a structured bill of processes and bill of materials, it can be useful to review those, to see what the processes look like and how complex they actually are.

**Demand volume (12)**
The Demand volume box describes the level of demand during a certain period. This can be measured mainly quantitively by looking at the order data. Graphs of the overall demand can be made, to see what has actually happened and how this has impacted the company. In the current situation, it is also useful to look at the demand patterns per country and per customer, to see which countries and customers are impacted highly.

**Data analysis DASCOVIMI companies**
For Company Ca, order data is analysed. First, a graph of the overall demand is made, to see what happened. This graph is shown in Figure 26. The demand is depicted in weight. It can clearly be seen that there is a big drop in demand April 2020, during COVID-19.
It can also be useful for a company to look more detailed into the demand, for example by looking at the number of orders per customer, or the number of orders per country. For Company Ca, the four countries to which Company Ca transports most of its orders are selected. These are France, Germany, Great Britain and Slovakia. The number of orders per country are depicted in Figure 27. In Figure 27, a similar trend can be seen as in Figure 26, where there is a big drop in orders in March and April 2020. Especially for Germany, the country to which Company Ca transports the highest number of orders, there was a big drop.

![Figure 27: Number of orders per country Company Ca](image)

Similar as per country, there can also be looked at the number of orders per customer. Figure 28 depicts the four biggest customers of Company Ca. It seems that the customer in the Food and Beverage industry was not that heavily impacted during the Corona crisis, since there was no big drop in demand. However, for all the customers of Company Ca that are active in the Automotive industry, it can be seen that there was a big drop in demand. This confirms the information that is obtained in the interviews, namely that the Automotive sector was very vulnerable during the crisis and that there was a big drop in demand in this sector.

![Figure 28: Number of orders per customer Company Ca](image)

**Demand uncertainty (13)**

The *Demand uncertainty* box is rather self-explanatory, since it concerns the uncertainty that a company faces about the demand of their customers. This uncertainty will always be there, but is probably higher in times of disruption. It is important to note that demand uncertainty is not the
same as demand level, because a change in demand level (either positive or negative), mostly indicates a higher level of uncertainty.

The demand uncertainty can be measured mainly qualitatively. Information about this can be obtained through interview or survey questions.

**Activity in impacted market sector(s) (14)**
With the box *Activity in impacted market sector(s)*, it is meant in how many industries the company is active. For a company that is active in a certain industry, it is important to know how this industry is impacted when a disruption happens. Data from an institution similar to the Dutch Centraal Bureau voor de Statistiek (CBS) can be used to see how much each industry is impacted, as compared to data from last year. This can give insights in which industries are performing well in times of crisis and which are under high pressure.

The *Activity in impacted market sector(s)* box can be measured quantitively. In annual reports or order data from companies, it can be seen in which sectors they are active. If companies are active in very few sectors, this is a higher risk, because when that specific sector is impacted, they may lose a lot of orders.

It can also be analysed qualitatively, by obtaining information through interview or survey questions.

**Data analysis statistical information sources**
It can be useful for a company to create a pie-chart which shows in how many industries they are active, and which industries are the biggest. For Company Ca, the number of orders in each industry is calculated and this is used to create Figure 29. In this figure, it can be seen that 81.23% of the business of Company Ca is in the automotive industry. This makes them very vulnerable when something happens in this industry, which is also seen during the Corona crisis.

![Figure 29: Pie-chart of industries in which Company Ca is active](image)

In Figure 29 above it can be seen that Company Ca is active in mainly 2 industries, namely Automotive and Food & Beverage. The Automotive industry can be then split up into two parts, namely OEM and Suppliers. In Figure 30 below, it can be seen that both of these are impacted highly during the Corona pandemic, since there is a big drop in number of orders. For the Food & Beverage industry on the other hand, there is a stability and even a growth in the number of orders during the Corona crisis.
Customer collaboration (15) and Supplier collaboration (22)
The boxes Customer collaboration and Supplier collaboration are rather similar, since they concern how much information and what kind of information a company shares with their customers and suppliers respectively, and how much information and what kind of information their customers and suppliers share with them. In the existing literature concerning supply chain disruptions, it came forward that information sharing is an important factor of collaboration, and therefore supply chain resilience (Kamalahmadi & Parast, 2016). This indicates that it is important to keep track of this information. It can be obtained mainly qualitatively, by conducting interviews and by conversations with customers and suppliers.

Dependency on impacted modality (20)
The box Dependency on impacted modality concerns the dependency of the company on certain modalities, such as road, air, sea, rail and pipeline. During the Corona crisis there was a decrease of belly freight, so the companies that were dependent on only this modality were highly impacted. The number of modalities that a company is dependent on can be found in the annual report, but it can also be obtained qualitatively by interviews or a survey.

Single sourcing from impacted supplier (21)
This box is about the dependency of a company on supplier(s) for a certain part or material. For the companies in the DASCOVIMI consortium, two companies indicated that they have a single sourcing strategy. For some companies single sourcing is the only option because of the complexity of the components that need to be delivered. They indicated that they never faced any issues concerning the single sourcing, until the Corona crisis. Therefore, only the single sourcing of suppliers that are impacted due to the disruption will lead to issues.

The dependency on suppliers can be measured qualitatively and quantitively. In supply data, the number of suppliers per product, material or component can be obtained. Furthermore, in qualitative interviews and surveys, questions can be asked concerning the number of suppliers of a company. Example questions that have been used in this research concerning this topic can be found in Appendices A and B.
5.4 Relations in generic CE diagram

Between the elements in the generic CE diagram, certain relations exist. These relations are defined for the link between two elements, e.g. the relation from element A to element B, keeping all the other elements (in the CE diagram) unchanged. A positive relation (+) means that an increase in (or occurrence of) element A results in an increase in (or occurrence of) element B. A negative relation (-) means that an increase in (or occurrence of) element A results in a decrease in element B. The defined relations can be found in Figure 31 on the next page and will be described in this section. It should be noted that the relations between the elements are general relations that are based mainly on the findings of this research, on logical reasoning and on existing literature. However, there might always be exceptions indicating a possible opposite relation. There are two exceptions that were striking during the Corona crisis and this research, which are indicated in Figure 31 with a *.

Explanation of relations

There are some relations in the CE diagram that may not be straightforward and need some further explanation. These explanations can be found below.

The negative relation from Pandemic occurrence (26) to Consumer trust (16)
The Pandemic occurrence box can obtain either the value 0 or the value 1: 0 in case there is no pandemic and 1 in case there is a pandemic. In the data analysis in the section above (see Figure 15 and Figure 16), it can be seen that during a time of pandemic, in this case the COVID-19, the consumer trust decreased drastically. So, when the value of Pandemic occurrence is 1, the value of the Consumer trust is low, hence the negative relation.

The negative relation from Pandemic occurrence (26) to Consumer income (17)
Similar as described above, the Pandemic occurrence box can obtain the value 0 or 1. In the data analysis in the section above (Figure 18 and Figure 17), it is shown that there is a higher number of unemployed people and a lower consumer spending during the Corona pandemic. This combination indicates that the consumer income during a pandemic is lower than usual, implying a negative relation between Pandemic occurrence and Consumer income.

The positive* relation from Consumer trust (16) to Demand volume (12)
When there is a higher consumer trust, it means that people have more trust in the economy and are more willing to spend money. It is obvious that this results in people buying more goods or services and with that higher demand volumes. This indicates a positive relation between Consumer trust and Demand volume. During the Corona crisis, something happened which shows an exception for this positive relation. Although the consumer trust dropped drastically during the pandemic (see Figure 15 and Figure 16), the demand volumes for grocery stores and certain products, such as toilet paper, skyrocketed because people were afraid and therefore started hoarding. This indicates that the relation is not strictly positive, hence the *.

The positive relation from ICT preparedness (10) to Working from home (18)
In the relation between ICT preparedness and Working from home, the degree to which companies have ICT systems (such as Teams, and a well working VPN connection) in place to facilitate the working from home are under consideration. There is a positive relation, because a high level of ICT preparedness indicates a better ability to work from home for employees.
Figure 31: CE diagram with relations between elements
The positive relation from Pandemic restrictions (19) to Working from home (18)
The box Pandemic restrictions can obtain the values 0 or 1: 0 when there are no restrictions and 1 when there are restrictions, such as lockdowns and the 1.5-meter rule during the Corona pandemic. Working from home in this context concerns the number of people in a company that have to work/are working from home. When there are pandemic restrictions, more people have to work from home, so there is a positive relation between Pandemic restrictions and Working from home.

The positive* relation from Number of people at workplace (24) to Human output (23)
In general, the relation between Number of people at workplace and Human output is perceived as positive. Namely, the more people at the workplace, the higher the output. However, in this research another finding came forward. One of the interviewed companies indicated that during the Corona crisis they had a high illness percentage, so there were less people at the workplace. However, the output was the same as, or even higher than, before, indicating a negative relation between Number of people at workplace and Human output. This was because the employees that were present at the workplace were more motivated to do the work and have a good output. Also, the people were able to do the work with less disturbances by other employees. This is most likely an exception to the rule, and in general the relation will still be positive. However, because of this finding, it cannot be stated that the relation between Number of people at workplace and Human output is strictly positive, hence the *

The positive relation from Number of people at workplace (24) to Quality of operations management (6)
The number of people at workplace can, during a pandemic, be influenced by the number of people that are ill in a company, and pandemic restrictions such as the 1.5-meter rule. When there are more people ill, there will be less people at the workplace, and similar, due to the 1.5-meter rule there can also be less people in the workplace than initially planned. When there are less people in the workplace than planned, the employee planning needs to be adjusted, which is part of the operations management. When the employee planning needs to be adjusted, operations management is more difficult, indicating that the quality of operations management can reduce. Therefore, there is a positive relation between Number of people at workplace and Quality of operations management; the less people (unexpected) at the workplace, the lower the quality of operations management.

The negative relation from Customer collaboration (15) to Demand uncertainty (13)
Customer collaboration is about the degree to which customers share information and data with the company. Information sharing is an important tool in dealing with the problems that arise with uncertainty in demand and supply (Ryu, Tsukishima & Onari, 2009). Therefore, when there is a better customer collaboration, the demand uncertainty will be lower, so there is a negative relation between the two.

The positive/negative relation from Working from home (18) to Reliability in operations (7)
The Working from home can have both a negative and a positive effect on the Reliability in operations. From the interviews with the DASCOVIMI companies, it became clear that some employees are more effective and efficient when they can work from home; this implies a positive relation between Working from home and Reliability in operations. On the other hand, some people experienced problems with the working from home and certain operations could not be executed when working from home, such as picking and packing in a warehouse or assembling a product in a production facility. This implies a negative relation between Working from home and Reliability in operations. It is also possible that no effect is visible, because the positive and negative relations can cancel each other out.
The positive relation from Dependency on impacted modality (20) to Delay in supply (9)
In the interviews with the DASCOVIMI companies, it came forward that certain modalities were severely impacted due to the Corona crisis. Especially belly freight was highly impacted, since there were (almost) no passenger flights anymore. Also, the modality road was impacted, which was mainly caused by the closing of borders by governments. During the interviews it became clear that because of this impact on the modalities, companies faced issues with the supply of goods. These issues concerned both that goods were delivered too late, and that goods were not delivered at all. This implies the positive relation between Dependency on impacted modality and Delay in supply.

The negative relation from Supplier collaboration (22) to Delay in supply (9)
Supplier collaboration in this context mainly concerns the information that a company shares with its suppliers and vice versa. When there is a good collaboration between a company and its suppliers, this indicates that there is more information sharing. Research of Hall & Saygin (2012) showed that information sharing improved the on-time delivery rate. This indicates the negative relation between Supplier collaboration and Delay in supply, namely; the higher the collaboration, the lower the delay.

The positive relation from Human output (23) to Reliability in operations (7)
Human output relates to the total amount of acceptable output during a period of time that is achieved by employees. When the acceptable output is high, it has a positive impact on the reliability in operations. Hence the positive relation from Human output to Reliability in operations.

The negative relation from Complexity in processes (11) to Quality of operations management (6)
When there is a lot of complexity in both internal and external processes within a company, the material and employee planning, and also forecasting can be more difficult. These are all aspects of operations management, so an increase in complexity in processes can lead to a reduction in quality of operations management. This explains the negative relation between Complexity in processes and Quality of operations management.

The negative relation from Complexity in processes (11) to Reliability in operations (7)
The explanation for this relation is similar to the reasoning for the previous relation. Once the processes are more complex, it can be more difficult to carry out the operations and to stick to the plans that are made in the operations management. Therefore, the relation between Complexity in processes and Reliability in operations is negative.

The negative relation from Delay in supply (9) to Quality of operations management (6)
When goods are delivered too late, it can result in rescheduling of operations. This rescheduling will have a negative impact on current material and employee planning, and thus on the quality of operations management. Therefore, there is a negative relation between Delay in supply and Quality of operations management.

The positive relation from Reliability in operations (7) to Revenue (2)
A company is reliable if it is able to perform its operations according to plan. When a company is able to perform its operations better than planned beforehand, so when it achieves more output, the revenue will increase. When a company performs their operations worse than planned, the revenue will logically decrease, since they have less output. Therefore, there is a positive relation between Reliability in operations and Revenue.

The positive/negative relation from Reliability in operations (7) to Cost of operations (3)
Similar as above, Reliability of operations concerns the ability of a company to carry out the operations according to the plan that has been set before. So for example, is the company able to deliver the right amount of goods on time, is there a need for rescheduling in the operations etc. The reliability of operations does have an impact on the cost of operations; a higher reliability in
operations implies an improvement of a plan, which can result in lower costs. However, whether a company is reliable in its operations, does not necessarily mean that the costs will decrease. A higher reliability in operations can also incur higher costs, when, for example, extra material or extra employees are needed to achieve this higher reliability. Therefore, the relation between Reliability in operations and Cost of operations can either be positive or negative.

The positive relation from Fixed assets structure (4) to Cost of operations (3)
In the interviews it came forward that Company A had few fixed assets. During the Corona crisis, this was positive for them, because they could easily get rid of for example warehouses and trucks, reducing their costs. On the other hand, Company C indicated that they did have a lot of fixed assets, and that this increased their costs during the crisis. The combination of these two examples imply that there is a positive relation between Fixed assets structure and Cost of operations.

Obvious relations
The other relations in the CE diagram are rather obvious and do not need further explanation. These are the following relations:

- The positive relation from Pandemic occurrence (26) to Pandemic restrictions (19)
- The positive relation from Pandemic occurrence (26) to Illness percentage (25)
- The positive relation from ICT preparedness (10) to Quality of operations management (6)
- The negative relation from Pandemic restrictions (19) to Training of personnel (8)
- The negative relation from Pandemic restrictions (19) to Number of people at workplace (24)
- The negative relation from Illness percentage (25) to Number of people at workplace (24)
- The negative relation from Activity in impacted market sector(s) (14) to Demand volume (12)
- The negative relation from Working from home (18) to Training of personnel (8)
- The positive relation from Single sourcing from impacted supplier (21) to Delay in supply (9)
- The positive relation from Consumer income (17) to Demand volume (12)
- The positive relation from Demand volume (12) to Revenue (2)
- The negative relation from Demand uncertainty (13) to Quality of operations management (6)
- The positive relation from Training of personnel (8) to Reliability in operations (7)
- The negative relation from Delay in supply (9) to Reliability in operations (7)
- The positive relation from Quality of operations management (6) to Reliability in operations (7)
- The positive relation from Fixed personnel structure (5) to Cost of operations (3)
- The positive relation from Revenue (2) to Profit margin (1)
- The negative relation from Cost of operations (3) to Profit margin (1)
6. Recommendations for restarting supply chains

In disruption management, there are three main phases found in existing literature. These are the discovery, recovery and redesign phase (Macdonald & Corsi, 2013), see Figure 1. In the discovery phase, it is important to detect the disruption as soon as possible. Next, in the recovery phase, actions should be taken to return to the original state (or a desired state, if business conditions have changed). Finally, in the redesign phase, actions need to be taken or changes need to be made in order to be better prepared for when a next disruption happens. The recommendations that are made based on this research are structured into these three phases.

6.1 Discovery

**Critically analyse and monitor internal performance and external information.**
In order to be able to detect a disruption as soon as possible, it is important to frequently monitor certain information and be critical when analysing it. In the survey, it came forward that companies are monitoring their financial information more frequently during the Corona crisis. Additionally, monitoring inventory levels and KPIs (more frequently) can also be beneficial in early discovery of issues related to a disruption. How quickly a company recognizes that a disruption is occurring is vital. Only then can recovery to the original state of the supply chain begin (Macdonald & Corsi, 2013). Additionally, a company should also have a team that monitors what is happening around the world and how this can impact the company.

6.2 Recovery

**Make changes to processes on the spot, for companies that have (some) flexibility in their operational processes.**
Flexibility in operations proved to be a core feature to ensure high resilience with respect to disruptions. Regarding flexibility in operational processes, it emerged from the interviews that for some of the companies this was one of the key elements allowing them to mitigate the production (and, therefore, the revenue) loss due to the Corona crisis. In particular, both Company B and Company D highlighted how they were able to reorganize and make changes to their processes on the spot, to face the disruption and related issues like, for instance, delays in supply and limitations on the access to the factory. Company B was flexible in changing the sequence in the production of machines by dynamic planning and setting up knowledgeable multidisciplinary teams on the spot. Company D was also flexible in their production sequence, partly because they have short set-up times on their machines and because they produce small batches. This was convenient during the Corona crisis to keep the supply chain up and running, and it was a major reason for the fast recovery. In order to make changes on the spot, it is important that different business units in a company, e.g. production and engineering, work closely together so they can share their knowledge about the operations. However, it should be noted that not all (parts of) processes can be flexible. In such a case, a recommendation can be to have strategic emergency stock and/or (higher) buffer inventories. This recommendation will be elaborated on in the redesign section below.

**Ensure that there is transparency in the supply chain, or to increase transparency during the disruption, to improve recovery.**
Enhancing the transparency and visibility in the supply chain enhances the resilience of all the involved parties against disruptions (Christopher & Peck, 2004; Scholten & Schilder, 2015). From all the interviews, it emerged that a particularly challenging factor in determining strategies to react to the Corona disruption was the lack of transparency from their suppliers and/or customers, increasing the uncertainty in their own operations. Of course, transparency in the supply chain is also beneficial when there is no disruption, so an increase in transparency should be permanent.
Reduce costs by scaling down on flexible assets and personnel, for companies that have a light assets and personnel strategy.

Fixed assets and fixed personnel turned out to have a negative impact on the overall resilience of a company during the Corona crisis. Company C is a company that indicated that it has a lot of fixed assets and fixed personnel, which created some issues during their crisis management. However, Company A, with its assertive strategy, flexible structure and high scaling capacities, was able to significantly reduce the costs during the crisis by reducing its assets and personnel, e.g., terminating suppliers’ contracts and laying off flex workers. This cost reduction enhanced the recovery of this company during the Corona crisis. It might be argued, however, that the long-term consequences of such policies could lead to a lack of trust with the supply chain partners.

Analyse governmental regulations on a regular basis such that operations can be managed and adjusted, and that they meet the restrictions in the respective countries.

When there is a pandemic, governments impose containment measures that companies must adhere to. During the interviews, especially with Company C, it became clear that there was a lot of unclarity because every country made its own restrictions and there was not one policy for Europe as a whole. In order to adhere to all the different measures, companies have to make changes in the execution of their operations. This ambiguity in governmental restrictions made it more challenging to manage operations smoothly and recover from the impact of the pandemic.

Not solely focus on internal business, but also monitor suppliers, customers and competitors to improve recovery.

Companies that are impacted by a disruption such as a pandemic, spend most of their time on keeping their own business up and running and trying to solve internal issues related to the disruption. However, it is also important to closely monitor how suppliers and customers are holding up, for example by (more frequently) monitoring their financial position. Issues at suppliers and customers, especially at very big and critical suppliers and customers, can have a massive impact on the operations of a company. By closely monitoring them, problems can be noticed timely and actions can be taken to mitigate the effect on the own business. It may be needed to help the supplier or customer with for example the planning of their operations or supporting them financially. An example supporting this is of Company D; this company helped suppliers by paying them earlier, and providing extended forecasts, which led to mitigation of the effects on their own operations. Besides suppliers and customers, it can also be beneficial to monitor how competitors are doing and what actions they are taking, because this can have an impact on demand levels and own operations. As an example, Company A experienced higher demand of current customers and obtained additional customers because some of its competitors were struggling during the Corona crisis.

Focus on employees during a disruption, where employees are being informed and involved, and where (informal) social contacts are being retained.

A disruption does not only impact the operations of a company, it also affects a company's employees in different ways. During the Corona crisis, working from home became the new standard. The interviewed companies all mentioned that this working from home resulted in less informal and social contacts between employees, and that they expect mental health issues in the (near) future among their employees. They indicated that it is important to acknowledge this and to try come up with new ways to preserve social contacts and give them personal attention. Furthermore, besides the need for transparency in the supply chain, it is very important to increase transparency within the company and involve employees when it comes to decisions making during the disruption. Employees should be aware of what is happening, what decisions are made and what is expected from them. By informing and involving them, there will be a higher level of willingness to
change and they will be more motivated (Gilley, Gilley & McMillan, 2009), which will have a positive effect on the recovery of a company.

6.3 Redesign

**Evaluate the ICT infrastructure and make sure that it is reliable and up to date.**
The presence of reliable and updated ICT systems is of crucial importance to ensure business continuity, especially when the physical workspace is not (fully) accessible. The presence of reliable ICT systems supported the business continuity of the operations during the pandemic allowing people to keep working from home, thus reducing the impact of the restrictions in place on the overall production. Furthermore, they provided a means for people to be in contact with their colleagues during the lock down, thus preserving, to a given extent, the workspace community, with positive effects both on personnel’s morale and their productivity. All the interviewed companies highlighted the important role played by their ICT systems in keeping their business going during the pandemic.

**Have a clear documentation and representation of processes related to operations management, with an information system in place to support the operational processes.**
The systematic coupling of ICT systems with operations management is highly beneficial to enhance the efficiency of the operations and it can represent a valuable aid in times of crisis. Having a clear documentation and an explicit representation of the supply chain network structure and of the processes related to the operations management, together with information systems tailored to support operational processes (e.g., WFM, SAP, ERP), allows to standardize and simplify process management, thus enhancing efficiency performance, as well as to identify in advance potential exceptions/issues and work out appropriate solutions. These systems also facilitate an effective monitoring of e.g. process KPIs, financial data and inventory levels, which allows a timely detection of possible bottlenecks or issues (as mentioned before) and providing information for their resolution. Furthermore, they greatly enhance the transparency of the operations, enabling an efficient flow of information among the different actors involved in the processes. Among the interviewed companies, Company A and Company B emerged like the ones with the strongest, process-aware information systems. Company D stood out for the high standardization of their processes and the presence of several exception management plans. However, while the benefits of these solutions are widely acknowledged among the interviewed companies, it also emerged that the full potential of these systems is often not exploited yet. All the interviewed companies reported an insufficient level of integration of information systems among different departments, as well as an often incomplete flow of information. Very often, both managers and employees had the feeling to miss the right information at the right moment. Having a clear documentation of the processes can be useful to deal with the complexity in processes. Since there is a negative relation between Complexity in processes and Quality of operations management, and Complexity in processes and Reliability in operations in the CE diagram, if this complexity can be reduced by the clear documentation, the quality of operations management and the reliability in operations will be improved.

**Have a contingency plan in place for when a disruption happens.**
An interesting finding that emerged in the interviews was that while all the companies acknowledge the importance and the benefits of having a contingency plan in place, not all of them had a suitable one available. Both Company B and Company D had a strong continuity plan, which allowed them to react quickly and in an organized way to the disruptions caused by Corona. There was a clear governance and employees knew what to do and who was responsible for what. Furthermore, because of the business continuity plan, the insurance fees that Company D must pay are less. Company A did not have a plan, and it took three weeks to draw one suitable to manage their
activities during the disruption. Similarly, Company C did not have a plan, but made one during the crisis to be prepared to deal with future scenarios in which the volumes remain low. Companies that do already have a contingency plan in place when a disruption happens, should evaluate this plan afterwards to analyse if it was appropriate and whether changes need to be made to improve the plan.

**Have strategic emergency stock to be able to reduce the impact of a disruption.**
A common element for Company B and Company D to keep the production running, besides the resequencing of processes, was that they both had some level of redundancy; Company B was able to use spare parts to compensate for the delayed parts, and Company D benefited from some additional stock in their warehouses. While redundancy of course also comes with some additional costs when no emergencies are in place, it proved to be a valuable mean to keep the production levels stable in case of disruption. This complements the findings in literature about keeping strategic emergency stock and buffer inventories by respectively Sheffi (2001) and Atan & Snyder (2012). However, because of the additional costs for keeping such an inventory, an analysis of the trade-off between advantages/disadvantages in different scenarios is advisable.

**Evaluate market strategy and have a diversified customer base if possible.**
Having a customer portfolio which is concentrated on only few markets proved to be an issue during the Corona crisis. For example, Company C is mainly focused on the automotive industry, which was an industry that was highly impacted during the crisis. The drop in automotive demand had a big impact on the total demand of Company C, because they are so dependent on this industry. This indicates that it can be a good strategy to have a more diversified customer portfolio and focus on different markets. When this is done, the impact of a drop in demand in one specific market will be lower on the total demand of the company. After the company has (partly) recovered from the disruption, it can be useful to evaluate in which markets the company is active, and which of these markets were impacted severely during the disruption. Of course, it should be noted that this is dependent on the type of disruption and is not necessarily the same when a next disruption happens. However, it still gives the company the possibility to see if they should focus on more markets, or different markets than they focus on now. It should also be noted that some companies offer a very specific good or service, and therefore are not able to diversify in their customer base. When this is the case, it is important for a company to have a good relationship with its customers. This will be more elaborated on in the next recommendation.

**Make sure there is a partnership atmosphere in the whole supply chain.**
In any supply chain, and especially during times of crisis, it is important to have a good partnership atmosphere between a company and its suppliers and customers. Such a partnership atmosphere can include visibility and transparency between customers and suppliers and the company, but also helping out customers and suppliers when there is a need for this. Investing time, effort and maybe even money in these relations can be beneficial to the company in the long term, to avoid losing actors that might be difficult to replace within the chain in a future disruption. This investment can also lead to suppliers and/or customers helping out your company when issues (related to disruptions) occur. The interviews showed that good personal contact and communication between different companies in the supply chain helped in the mitigation of the impact of the disruption.

**Evaluate how suppliers and customers behaved and how reliable they were during the crisis.**
In the recovery phase, it was suggested to monitor suppliers and customers during a crisis in order to notice issues timely and take actions if necessary. After a company has recovered from a disruption, it can be useful to evaluate its suppliers and customers, to see which ones got through the crisis without major issues and which ones did face major issues, impacting the own business. It can be
checked how reliable the particular supplier/customer was during the crisis, if they were prepared and if they made any changes now to be better prepared for a future disruption. Based on this evaluation, strategic decisions can be made whether to keep working with certain suppliers/customers or search for other, more reliable ones.

**Evaluate components, processes and management, how they changed during the crisis, and decide whether permanent changes need to be made.**

Another recommendation that came forward in the recovery phase was about the flexibility in processes, and the ability to re-sequence certain production steps. When the company has recovered from the crisis, it can be useful to evaluate how these changes impacted the operations and whether the changes that are made should be permanent or not. It can for example be possible that because of the changes that needed to be made on the spot, the operations became more efficient. Company D indicated for example that there was less interference by managers on the production site during the Corona crisis. This change in management approach resulted in production personnel being more productive. Besides the re-sequencing of certain production steps and the different management approach, there is also another example of a change in operations that might become a permanent change. This is related to working from home. During the interviews it came forward that, before the Corona crisis, several companies did not think that working from home was possible for them. During the Corona crisis however, they did not have a choice and were forced to work from home. Some companies indicated during the interviews that they think there will be a permanent change to a hybrid form of working from home and working at company locations. Another example is again of Company D; they indicate that they have certain criticality levels for their components, illustrating which components are of high importance for the production and which are less important. During the Corona crisis they found out that these criticality levels were not always correct; there was one particular component which they scaled at a low criticality level, which was actually very important in their process. Therefore, they indicated that they should re-evaluate the criticality levels of their components. These are some examples of the evaluation of components and management, and changes in processes that came forward during the crisis which might be permanent. Of course, there can be more changes that need to be implemented.

**Evaluate (insurance) contracts to be sure that you have reliable (insurance) partners with reliable contracts.**

Companies can insure themselves against risks and pay insurance fees for this. In the interview with Company Ca, it came forward that their insurance companies all of a sudden lowered the credit coverage during the Corona crisis. This resulted in Company Ca having to lower the amount of outstanding receivables from their customers to be less exposed to the risks associated with outstanding receivables. As a company, you insure yourself especially for uncertain situations like a disruption and you do not want this to happen. Not only insurance contracts, but also contracts with suppliers and customers and how the suppliers and customers act upon these contracts during disruptions can reveal possible issues.

As both the versatility of the recommendations and the versatility of the generic cause-effect diagram suggest, this research covers numerous business facets at the same time. While disruption management literature mostly focusses on one specific business facet, this research presents a comprehensive overview of issues regarding disruptions and directions for the mitigation and management of the impact of a disruption, looking at various business aspects at once.
7. Conclusion

In this thesis, the impact of the Corona virus disruption on supply chains is investigated with a focus on the financial impact. The aim of this exploratory research was to provide companies with first insights on how the Corona pandemic impacted supply chains and how to deal with disruptions in a more effective manner. To guide this research and be able to provide those insights, a research question and three sub-questions were formulated. The first sub-question was:

*How has the Corona crisis affected the financial performance of companies?*

This sub-question is examined with a quantitative analysis of publicly available stock and market data which is described in the section ‘Analysis of impact on financial performance’. For a sample of 89 firms active in four different industries, abnormal returns associated with the Corona crisis were estimated and checked for statistical significance. From this analysis, it can be concluded that the Corona crisis had a negative effect on the financial performance of companies. Firms lost on average 31.77% of their shareholder value as a result of the Corona crisis during the one-month period after the first containment measures in Europe. A comparison between the different industries indicated that the negative financial impact of the Corona crisis was less for companies in the Food & Retail industry.

After investigating the overall financial impact of the Corona crisis, case studies were performed with the DASCOVIMI consortium partners and a survey was conducted with ESCF members to gather more detailed information regarding the (financial) impact of the Corona pandemic. These served as input for answering the other two sub-questions. The second sub-question was:

*Which elements influence the impact of a disruption on a company’s financial variables, and how are these elements related?*

The lessons learned from the interviews and the survey results provided a generic diagnosis of problems and their causes that the companies experienced during the Corona crisis, and which eventually had an effect on the financial performance of the firms. All these problems and causes (called elements) were structured into one generic cause-effect diagram which tracks the causal relationships from the pandemic occurrence on the left to the financial performance (revenue, costs and thereby profit margin) on the right. A description of all the elements and data analyses that can be performed to detect the impact of a disruption on those elements is given in the section ‘Explanation and descriptive data analysis generic CE diagram’. The relations between the elements are described in the section ‘Relations in generic CE diagram’ and have been based on the findings of this research, on logical reasoning and on existing literature. It can be concluded that the financial impact of a disruption is influenced by elements related to demand, supply, people/personnel, ICT infrastructure, operations management and asset structure.

Besides providing a diagnosis of problems and their causes, the lessons learned from the interviews and the survey results also provided information regarding the actions taken by firms to deal with the disruption. Additionally, the firms mentioned in the interviews that there were actions that they did not (yet) take, but that would have improved recovery. All of these actions can be found in the section ‘Lessons learned’ and the section ‘Recommendations for restarting supply chains’, answering the last sub-question:

*What are the different actions taken, including actions regarding financial variables, by firms to recover from the disruption?*
Based on the information and insights gathered with the three sub-questions and based on the designed generic CE diagram, the research question can be answered:

*How can companies manage certain financial variables to prepare for, or recover from, a supply chain disruption like the Corona crisis?*

The developed CE diagram helps companies by providing a generic tool for diagnosing the problems that can arise due to pandemics and other big disruptions. It can be used to identify recovery or redesign strategies to break the causal chain between pandemic occurrence (major disruption) and the impact on a company’s financial performance (revenue, costs and thereby profit margin). A firm can identify where it may face problems and follow its path to understand how it will affect its operations and profitability. Based on the elements in this path, a list of possible actions or interventions can be made to manage and mitigate the financial impact of the disruption. As an example, a firm with revenue as a major dependent variable would like to keep its revenue constant, despite the occurrence of the pandemic. In this case, the firm should take actions/interventions to influence demand volume and improve reliability in operations, as these aspects have a direct positive influence on revenue. Typically, a company can influence demand to some extent, but cannot get it completely back to pre-pandemic levels immediately. Improving reliability in operations implies spending money on for example overtime, creation of material buffers and additional resources. All of this brings more costs. This implies that there needs to be a trade-off between the importance of keeping revenues at a particular level against the additional costs of doing so. The recommendations for discovery, recovery and redesign in the section ‘Recommendations for restarting supply chains’ provide concrete guidance for developing effective actions or interventions upon discovery of a major supply chain disruption, during the recovery phase after that, and during the redesign phase to prepare for future disruptions.

In this thesis, insights have been given into how the Corona pandemic has impacted companies and how to deal with disruptions in a more effective manner. A particular company can identify what measures are appropriate in its situation by using the developed cause-effect diagram to find the applicable elements, causal chains and relations for problems that occur during a disruption. In that way, effective actions or interventions can be taken to mitigate and manage the financial impact of the disruption.
8. Limitations and further research

In this section, some limitations of the research and ideas for further research are described.

A limitation of the quantitative data analysis that is performed to investigate the impact of the Corona pandemic on the financial performance of firms, is the (relative) small sample size. In comparable event study methodologies estimating abnormal returns described in literature, the sample size is often bigger than 400. In addition, companies from only four industries have been examined. Including companies active in other industries would be a good extension to this analysis to obtain a more complete insight on the financial impact of the Corona crisis. Possible further research could also include company specific characteristics such as number of employees, market value or capital structure that can be analysed to identify factors influencing the magnitude of the change in stock prices due to the disruption. Another direction for further research is to perform the same analysis for other crisis events in the past, such as the 9/11 terrorist attacks or the global financial crisis in 2008, and compare the financial impact of the Corona crisis with the financial impact of those crises. This way, the magnitude of the financial impact of the Corona crisis can be put into perspective.

A limitation of the case studies is that only companies in the Manufacturing industry and Transport & Logistics industry were involved. Although a survey was sent out to ESCF members to gather more information, the majority of respondents were again active in manufacturing or logistics. Additionally, only four case studies were performed and the number of responses to the survey was relatively small. Therefore, further research is needed to verify the developed CE diagram with more companies in other industries and possibly complement the CE diagram with elements that have not been brought up during this research.

Additionally, the analyses that have been performed on the provided data of the consortium partners were only descriptive. To be able to move to predictive analyses, and eventually prescriptive decision support, vast amounts of data are required. Unfortunately, and given the ‘pressure-cooker’ timeline of the DASCOVIMI project, those data were not readily available during the project. Furthermore, the consortium partners would not share some types of data that would have been interesting to analyse, presumably out of possible confidentiality issues or the fear to harm its competitive position. For example, further research could analyse the decisions regarding trade credit management made by companies during a disruption and how these affect the recovery of supply chain partners and itself, when this type of data is made available by companies.

Finally, a topic that was mentioned in all the interviews and also came back in the survey results, is issues related to working from home. Although working from home is not new, the scale and pace at which it is adopted during the Corona crisis is exceptional. Therefore, the effects of working from home during the Corona pandemic is an interesting topic for further research. For example, research can be performed on the effects of working from home on mental health of employees or on the productivity of employees.
References
DASCOVIMI (2020). Dinalog subsidy application plan.


Geelen, V.P.J. (2020). Research on supply chain disruption management: A systematic literature review and directions for future research


Appendices
Appendix A: Interview template Manufacturers

1A: General/department
In this part of the interview we are focusing on the world where you are offering your services. First, we want to get an understanding about your network structure, your customers, suppliers and the logistic service provider. The corona crisis has put our world to unexpected events and challenges. Therefore, we want to learn more about how your organization has addressed these challenges.

Network structure and challenges
- Do you have a visualization of your network?
  o Can you show/share it?

- How does your network structure look like?
  o What end-markets is the company supplying to?
  o How many steps are you away from your end customer?
    ▪ Upstreamness (position in supply chain)
  o Where are your customers, suppliers and logistics service providers located?
    (local/regional or global: stock points & production sites)
  o Has this changed during Corona?
- How did the lead times change due to the Corona crisis?
  ▪ Lead time from supplier to you
  ▪ Lead time from you to customer
  o Lead time effects
- How much visibility is there in the supply chain?
  o Can you track your goods/transport vehicles/parts?
    ▪ Information sharing in supply chain

- During the Corona crisis, what changes did you see in the way of working between supply chain partners?
  ▪ Dedicated meeting structure with suppliers (and customers)
  ▪ More collaboration/partnership, change in attitude and behavior
  ▪ Data transparency to create a common picture (think of Collaborative Planning)
  ▪ Good supply chain network relationships

- How many suppliers do you have?
  o Who are your key suppliers?
    ▪ Does the 80/20 rule apply?
  o Do you have new suppliers due to Corona?
    ▪ Uniqueness/replaceability
  o Did you lose any suppliers due to Corona?
    ▪ How vulnerable are your suppliers?
  o Are you using a dual/alternative sourcing strategy?
    ▪ If so, did it help you during the Corona crisis?
- If not, are you considering such strategy?
- How dependent are you on your suppliers?
- Risk profiling

- How important is your firm to your suppliers?
  - How many other customers does your supplier have?
  - Are you a main/priority customer/end-market for one of your suppliers?
    - Strict priorities
    - Fair share rules

- What happened to supply levels of critical materials/parts?
  - What caused this reduction or increase?
    - Lower/higher end-market demand? Reduction/increase over time?
    - Lockdown at customer sites
    - Production personnel at customer sites reduced in number
    - Other suppliers of your customers could not deliver, made other strategic choices.
    - Closing of borders/governmental restrictions

- How many customers do you have?
  - Who are your key customers?
    - What percentage of total customers are consistent/loyal customers?
  - How dependent are you on your customers?
    - Risk profiling
  - Did you lose (or gain) any customers due to Corona?
    - How vulnerable are you from your customers point of view?
    - If lost: is this due to their own cash crunch? Or did the customers switch to other suppliers?
    - Are you unique/replaceable?
  - How many alternative end-markets does your company have?

- For how many of your customers are you the main supplier?
  - How many other suppliers do these customers have?
  - How many are priority customers/end-markets?
    - Strict priorities
    - Fair share rules

- How does your competition look like?
  - How do they react to the crisis? What (financial) effects do they notice?
  - Did your competitive position change?

- How do you determine end-market demand?

- What happened to demand levels?
  - What caused this reduction or increase?
  - Is there a difference between the demand of your customer and the demand of the end-customer? (characteristic of bullwhip effect)
    - Is there transparency within the supply chain concerning demand?
  - Is this change influenced by the bullwhip effect?
    - Do you foresee a bullwhip effect?

- How do you manage your inventory?
How do you decide when/what to order?
- What forecast method do you use?
  - Single exponential smoothing, double exponential smoothing, Holt winters
- What changes did you make in the forecast due to the crisis?

- What transport modalities do you use?
  - How does your modality split look like?
    - Road, air, sea, train, pipeline
- How many transportation companies?
- Are you dependent on transportation of your suppliers/customers or is this contracted to a 3PL?
  - Risk profiling
- Under which incoterms do you buy and sell your products?
  - Did this change due to Corona?
    - Was there a necessity to take more leadership/control on this?
    - Incoterms: ownership of goods (seller and buyer): point of time during transportation?
- How do you make use of available truckload per truck?
  - How efficient is this?
    - A lot of empty spaces?
  - Is this changed due to Corona?
    - Due to transportation scarceness?
- How are your logistics service providers (transport) affected by the Corona Crisis?
- How are your warehouses/cross docks affected by the Corona Crisis?

**Process flows**

In this part of the interview, we want to ask questions about the processes. Generally speaking, a **business process** is a set of activities performed by a set of actors, according to a set of constraints, to deliver a product/service to a customer. When considering a supply chain scenario, this definition can be applied at two different levels, one “external” and one “internal”. The first one is the one that looks at the interaction among nodes. In the supply chain network, we can see to how many different nodes your company is connected. A process describing this interaction would show you the flows within the chain, e.g., would show you which (high-level) activities are carried out by each node and how all these activities together participate to obtain of the company outcome. Then, we delve into the internal processes: e.g. the set of activities that are performed to make sure they will receive the needed components, will be able to assemble them properly, and will send them in the right way. We want to stick to the level of the main processes

- Can you reconstruct the main steps of the supply chain process flow your company interacts with?
  - Activities involving interactions with the network nodes
  - Flow diagram
- Can you reconstruct your internal processes involved with respect to the supply chain?
  - Flow of each product, from when you receive the material to when you deliver it?
  - Flow diagram
  - How are activities organized within these flows?
  - Which processes and which departments are involved?
- e.g., purchase-to-pay, order-to-cash, production and logistics...?
  - Do you know, at each moment in the process, who is involved/responsible for a given task, and which resources are needed (e.g., machines, materials,...)?

- What were the main bottlenecks in the processes before the crisis?
  - Transportation, production, customers, suppliers
  - How have they changed during Corona?

- Which kind of problems do you experience within supply-chain related processes due to Corona?
  - Which ones were depending on internal problems, and which ones are related to suppliers/customers?
  - Did any certainties disappear because of the Corona crisis? If yes: which ones
    - Unlimited transportation
    - Disappearing demand
    - Supply of common goods
    - Workforce
  - Did you change processes and or procedures rapidly?
    - For example, which got stopped, which could continue, which ones had to be redesigned/rethought/ went through a governance changed

- Which kind of information you think you missed that would have helped you in better re-arranging your processes?

- What happened to production levels during the Corona crisis?
  - What caused this change in production levels/production plants?
    - Packaging materials
    - Production personnel (picking, unpacking, packing operators)
    - Transporting finished products
  - What measures did you take to adapt the production levels?
    - Reduce/increase production personnel in numbers
    - Use admin staff to support production (in case of increase)
    - More stock build-up
  - If applicable: How can you go back to old production levels/patterns?

**Expectations**

Die Hoffnung stirbt zuletzt (hope dies the last), Germans say. Out of every crisis something new arises. This part of the interview is primarily focusing on your expectations about how you foresee the future.

- Were you prepared for a big disruption like this?
  - Fear-based actions or calculated actions?

- How did you prepare?
  - Different scenarios/strategies with solutions
  - Safety/emergency stocks to cope with the excessive demand?
  - Spare/redundant (production) capacity
  - Supply chain visibility, flexibility, agility and collaboration
  - Changing your suppliers/warehouses to different locations in the world
  - Which of these procedures were valuable, and which ones turned out to be insufficient?

- What is your expectation for the coming months/years?
  - Do you expect certain changes to be permanent/long term?
• What challenges do you foresee when there is a second wave?
• How fast do you think the recovery (of the company and your department) will be?
  o Old levels or new normal
  o Are there challenges solved already? (demand, supply, production challenges)
    ▪ How much time did/does it take?
    ▪ How is it solved?
• Will you be prepared for a big disruption like this in the future and how?
• What did you learn from the Corona crisis?
  ▪ Strategic
  ▪ Tactical
  ▪ Operational

1B: Finance and performance

The coronavirus related shutdowns have affected all firms, big and small. Some are better prepared than others, some are just lucky, but most firms are dealing with some significant problems. Our research team is studying how firms recover from shocks. We can learn from firms that recover faster, by contrasting the actions they take compared to the firms that recover slower. These actions typically deal with proper management of margins, revenues, trade credit, inventories and short-term debt.

Furthermore, these actions differ between large and small firms. Larger firms can support many of their small-scale supply chain partners with proper trade credit management.

In order to carry out the analysis, we require some financial parameters from you from the past 6 quarters. Will you be willing to share the following information with us?

<table>
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<tr>
<th>Gross Margin</th>
<th>Short term debt</th>
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<td>Trade Credit</td>
</tr>
<tr>
<td>Days of Inventory Outstanding</td>
<td>Working Capital</td>
</tr>
<tr>
<td>Days of Receivables Outstanding</td>
<td>Number of Employees (Levels – Junior, Mid, Senior)</td>
</tr>
</tbody>
</table>

• What are your thoughts on the parameters described (differences)? Does your firm manage the data of these parameters? What are your thoughts on last 6 quarters, and do you have projections for next 4 quarters? Can you help us with the data requirements for analysis?
• Do you know the financial position of your suppliers and customers?
  o Do you consider this in the decision-making process?
• Are there changes in short term debt and trade credit policies in your firm due to Corona?
  ▪ A large focal firm can support its local supplier network by adjusting these policies. It is much harder and expensive to replace a long-term supplier, as compared to the cost of supporting them for a few quarters. Different policies can be implemented for different suppliers
    o If yes, what are these changes?
    o W.r.t. trade credit, how are you managing your suppliers and customers?
    o Small scale suppliers may feel the impact more than you, in what way can you support them (be a partner)?
- Paying for supplies early? What about customers? Will you ask them to pay you early, or will you give them more time?
  - What about short-term debt? Is it harder to borrow? What about your suppliers (especially small scale)? Are they having cash problems?
- How do your customers behave as a partner when it comes to sharing costs?
  - Did this change during the Corona crisis?
  - If necessary, in the future, do you think that are your customers are willing to pay you more when extra costs incur?
- What are the KPIs in your department?
  - At what level do you strive your KPI’s to be?
  - Did you reach those levels?
  - Is there an alignment on KPIs in the organization?
  - Have the KPIs changed during the Corona crisis?
  - When a problem arises, can you estimate its impact on your performance? If yes, how?
- How will the KPIs change in the coming months/years? [“the new normal”]

1C: ICT & Management information and reporting
During a crisis such as the corona virus, where normal functions do not function normal anymore, extra information is needed to make the right business decisions. This part of the interview focusses on the management information (and the necessary data) you need, to be able to make these decisions.

- Which kind of data do you store regarding your processes (e.g., BoP, BoM, anything else? RFID?) and on which systems/format (ERP, MRP)?
  - How?
    - Inventory, production, demand
- How do you currently monitor the status of your processes? Which indicators do you use and with which data?
  - Did you install new dashboards and or systems to monitor?
- How do you manage communications and interactions with other nodes in the chain?
  - How do you receive/transmit information on arriving/sent products/materials from/to other nodes in the network?
    - Is this communication only informal or actually stored as e.g. current status of an order, problems with communication?
  - How did this change due to Corona?

Besides the data storing capabilities in your company, has also dealt with the working from home situation.

- Was there a proper ‘digital solution’ in place?
  - Were there changes needed?
    - Digitalisation
  - Was there a budget for this?
- Do you think this are permanent?
- What did you learn from the data storing and working from home during corona?
1D: HR & Organization
Humans are crucial in any organization. Actually, organizations do not exist without people. This crisis has had an enormous impact on staff in the way they can do their work but also from a health perspective. This part of the interview is focusing on your staff and way of working, within the organization.

- During the Corona crisis, besides working from home, what changes did you see in the way of working in your department and between the departments in the company?
  - Dedicated meeting structure with suppliers (and customers)
  - More collaboration/partnership, change in attitude and behavior
  - Data transparency to create a common picture (think of Collaborative Planning)
  - Good supply chain network relationships
- How did the roles/functions in the department change during the Corona crisis?
  - Formal and informal leaders
- What was the impact of the Corona crisis on your workforce?
  - Did the illness rate among your employees change? Did this have a (negative) impact on your company
  - Did you retain the workforce?
    - Do you need new personnel now? And are they qualified and available?
    - Can the same work be done with less people?
    - Is the training of new personnel a bottleneck?
  - Was there any change in the staff hiring procedures?
    - Was there a stop in hiring people? Nobody applying?
  - Problems with working from home?
    - Was it possible? How do your employees experience it?
    - “new normal”: more working from home (becomes permanent)?
  - Can people work less hours due to restrictions?
    - Working in different shifts than before?

These were all our questions. Are there things that you want to add that can be useful for our research?

Appendix B: Interview template Logistic Service Providers

1A: General/department
In this part of the interview we are focusing on the world where you are offering your services. First, we want to get an understanding about your network structure, your customers, suppliers and the transportation modalities. The corona crisis has put our world to unexpected events and challenges. Therefore, we want to learn more about how your organization has addressed these challenges.

Network structure and challenges
- Do you have a visualization of your network?
  - Can you show/share/give it?
- How does your network structure look like?
○ What end-markets is the company supplying to?
○ How many steps are you away from your end customer?
  ▪ Upstreamness (position in supply chain)
○ Where are your customers, suppliers and logistics service providers located?
  (local/regional or global: stock points & production sites)
○ Has this changed during Corona?
• Did the corona crisis change the time to deliver a product to a customer?
  ▪ Lead time from supplier to you
  ▪ Lead time from you to customer
○ Lead time effects
• How much visibility is there in the supply chain?
  ○ Can you track your goods/transport vehicles/parts?
  ▪ Information sharing in supply chain
• During the Corona crisis, what changes did you see in the way of working between supply chain partners?
  ▪ Dedicated meeting structure with suppliers and customers
  ▪ More collaboration/partnership, change in attitude and behavior
  ▪ (Data) Transparency to create a common picture (think of Collaborative Planning)
  ▪ Good supply chain network relationships
• Do you have any (key) suppliers? If yes:
  ○ Do you have new suppliers due to Corona?
    ▪ Uniqueness/replaceability
  ○ Did you lose any suppliers due to Corona?
    ▪ How vulnerable are your suppliers?
  ○ Are you using a dual/alternative sourcing strategy?
    ▪ If so, did it help you during the Corona crisis?
    ▪ If not, are you considering such strategy?
    ▪ How dependent are you on your suppliers?
    ▪ Risk profiling
  ○ How important is your firm to your suppliers?
    ▪ How many other customers does your supplier have?
    ▪ Are you a main/priority customer/end-market for one of your suppliers?
      • Strict priorities
      • Fair share rules
• How many customers do you have?
  ○ Who are your key customers?
    ▪ What percentage of total customers are consistent/loyal customers?
  ○ How dependent are you on your customers?
    ▪ Risk profiling
  ○ Which markets do you serve?
    ▪ Marketing strategy
  ○ Did you lose (or gain) any customers due to Corona?
    ▪ If lost: is this due to their own cash crunch? Or did the customers switch to other logistic service providers?
- Are you unique/replaceable?
  - How many alternative end-markets does your company have?
- Marketing strategy
- For how many of your customers are you the main logistic service provider? (How dependent are your customers on your logistics service?)
  - Risk profiling
    - Do your customers have any other logistic service providers?
    - How many are priority customers/end-markets?
      - Strict priorities
      - Fair share rules
- How does your competition look like?
  - How do they react to the crisis? What (financial) effect do they notice?
  - Did your competitive position change?
- How do you determine end-market demand?
- What happened to demand levels?
  - What caused this reduction or increase?
    - Lower/higher end-market demand? Reduction/increase over time?
    - Lockdown at customer sites
    - Production personnel at customer sites reduced in number
    - Other logistic service providers of your customers could not deliver, made other strategic choices.
    - Closing of borders/governmental restrictions
- Do you have any kind of inventory? If yes: how do you manage your inventory?
  - How do you decide when/what to order?
  - What forecast methodology do you use?
    - Single/double exponential smoothing, Holt Winters
  - What changes did you make in the forecast due to the crisis?
- What transport modalities do you use to serve your customers?
  - How does your modality split look like?
    - Road, air, sea, train, pipeline
- How do you make use of available truckload per truck (FTL, LTL, efficiency)?
  - If you make use of other modalities, how does this translate to these vehicles (plane/train/boat)
  - How efficient is this?
    - A lot of empty spaces?
  - Has this changed due to Corona?
    - Due to transportation scarcity?
- How are your warehouses/cross docks affected by the Corona Crisis?

**Process flows**

In this part of the interview, we want to ask questions about the processes. Generally speaking, a business process is a set of activities performed by a set of actors, according to a set of constraints, to deliver a product/service to a customer. When considering a supply chain scenario, this
definition can be applied at two different levels, one “external” and one “internal”. The first one is the one that looks at the interaction among nodes. In the supply chain network, we can see to how many different nodes your company is connected. A process describing this interaction would show you the flows within the chain, e.g., would show you which (high-level) activities are carried out by each node and how all these activities together participate to obtain the company outcome. Then, we delve into the internal processes: e.g. the set of activities that are performed to make sure they will receive the needed components, will be able to assemble them properly, and will send them in the right way. We want to stick to the level of the main processes

- Can you reconstruct the main steps of the supply chain process flow your company interacts with?
  - Activities involving interactions with the network nodes
  - Flow diagram
- Can you reconstruct your internal processes involved with respect to the supply chain?
  - Flow of each product, from when you receive the material to when you deliver it?
  - Flow diagram
    - How are activities organized in those flows?
    - Which processes and which departments are involved?
    - Do you know, at each moment in the process, who is involved/responsible for a given task, and which resources are needed (e.g., machines, materials,..)?
- What were the main bottlenecks in the processes before the crisis?
  - Transportation/logistic, operation, production, suppliers, customers
    - How have they changed during Corona?
- Which kind of problems do you experience within supply-chain related processes due to Corona?
  - Which ones were depending on internal problems, and which ones are related to suppliers/customers?
  - Did any certainties disappear because of the Corona crisis? If yes: which ones
    - Unlimited transportation
    - Disappearing demand
    - Workforce
  - Did you change processes and or procedures rapidly?
    - For example, which got stopped, which could continue, which ones had to be redesigned/rethought/ went through a governance changed
- Which kind of information you think you missed that would have helped you in better re-arranging your processes?

Expectations
Die Hoffnung stirbt zuletzt (hope dies the last), Germans say. Out of every crisis something new arises. This part of the interview is primarily focusing on your expectations about how you foresee the future.

- Were you prepared for a big disruption like this?
  - Fear-based actions or calculated actions?
    - How did you prepare?
      - Different scenarios/strategies with solutions
      - Safety/emergency stocks to cope with the excessive demand?
      - Spare/redundant (production) capacity
Supply chain visibility, flexibility, agility and collaboration
Changing your customers/warehouses to different locations in the world
  o Which of these procedures were valuable, and which ones turned out to be insufficient?

What is your expectation for the coming months/years?
  o Do you expect certain changes to be permanent/long term? Which one?

What challenges do you foresee when there is a second wave?

How fast do you think the recovery (of the company and your department) will be?
  o Old levels or new normal
  o Are there challenges solved already? (demand, supply, production challenges)
    ▪ How much time did/does it take?
    ▪ How is it solved?

What did you learn from the Corona crisis?
  ▪ Strategic
  ▪ Tactical
  ▪ Operational

1B: Finance and performance
The coronavirus related shutdowns have affected all firms, big and small. Some are better prepared than others, some are just lucky, but most firms are dealing with some significant problems. Our research team is studying how firms recover from shocks. We can learn from firms that recover faster, by contrasting the actions they take compared to the firms that recover slower.
These actions typically deal with proper management of margins, revenues, trade credit, inventories and short-term debt.

Furthermore, these actions differ between large and small firms. Larger firms can support many of their small-scale supply chain partners with proper trade credit management.

In order to carry out the analysis, we require some financial parameters from you for the period of the past 6 quarters. Will you be willing to share the following information with us?

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• What are your thoughts on the parameters described (differences)? Does your firm manage the data of these parameters? What are your thoughts on last 6 quarters, and do you have projections for next 4 quarters? Can you help us with the data requirements for analysis?
• Do you know the financial position of your suppliers?
  o Do you consider this in the decision-making process?
• Are there changes in short term debt and trade credit policies in your firm due to Corona?
  ▪ A large focal firm can support its local supplier network by adjusting these policies. It is much harder and expensive to replace a long-term supplier, as
compared to the cost of supporting them for a few quarters. Different policies can be implemented for different suppliers

- If yes, what are these changes?
- W.r.t. trade credit, how are you managing your suppliers and customers?
- Small scale suppliers may feel the impact more than you, in what way can you support them (be a partner)?
  - Paying for supplies early? What about customers? Will you ask them to pay you early, or will you give them more time?
- What about short-term debt? Is it harder to borrow? What about your suppliers (especially small scale)? Are they having cash problems?

- How do your customers behave as a partner when it comes to sharing costs?
  - Did this change during the Corona crisis?
  - If necessary, in the future, do you think that are your customers are willing to pay you more when extra costs incur?

- What are the KPIs in your department?
  - At what level do you strive your KPI’s to be?
  - Did you reach those levels?
  - Is there an alignment on KPIs in the organization?
  - Have the KPIs changed during the Corona crisis?
  - When a problem arises, can you estimate its impact on your performance? If yes, how?

- How will the KPIs change in the coming months/years? [“the new normal”]

1C: ICT & Mngt information and reporting
During a crisis such as the corona virus, where normal functions do not function normal anymore, extra information is needed to make the right business decisions. This part of the interview focusses on the management information (and the necessary data) you need, to be able to make these decisions.

- Which kind of data do you store regarding your processes (e.g., BoP, BoM, anything else? RFID?) and on which systems/format (ERP, MRP)?
  - How?
    - Inventory, production, demand
- How do you currently monitor the status of your processes? Which indicators do you use and with which data?
  - Did you install new dashboards and or systems to monitor?
- How do you manage communications and interactions with other nodes in the chain?
  - How do you receive/transmit information on arriving/sent products/materials from/to other nodes in the network?
    - Is this communication only informal or actually stored as e.g. current status of an order, problems with communication?
  - How did this change due to Corona?

Besides the data storing capabilities in your company, ICT has also dealt with the working from home situation.

- Was there a proper ‘digital solution’ in place to work from home?
  - Were there changes needed?
Digitalisation
  o  Was there a budget for this?
  •  Do you think this is permanent?

•  What did you learn from the data storing and working from home during the Corona crisis?

1D: HR & Organization
Humans are crucial in any organization. Actually, organizations do not exist without people. This crisis has had an enormous impact on staff in the way they can do their work but also from a health perspective. This part of the interview is focusing on your staff and way of working, within the organization.

•  During the Corona crisis, besides working home, what changes did you see in the way of working in your department and between the departments in the company?
  ▪  Dedicated meeting structure
  ▪  More collaboration/partnership, change in attitude and behavior
  ▪  (Data) Transparency to create a common picture (think of Collaborative Planning)
  ▪  Good supply chain network relationships
•  How did the roles/functions in the department change during the Corona crisis?
  ▪  Formal and informal leaders
•  What was the impact of the Corona crisis on your workforce?
  o  Did the illness rate among your employees change? Did this have a (negative) impact on your company?
  o  Did you retain the workforce?
    ▪  Do you need new personnel now? And are they qualified and available?
    ▪  Can the same work be done with less people?
    ▪  Is the training of new personnel a bottleneck?
  o  Was there any change in the staff hiring procedures?
    ▪  Was there a stop? Nobody applying? No change?
  o  Problems with working from home?
    ▪  Was it possible? How do your employees experience it?
    ▪  “New normal”: more working from home (becomes permanent)?
  o  Can people work less hours due to restrictions?
    ▪  Working in different shifts than before?

These were all our questions. Are there things that you want to add that can be useful for our research?
Appendix C: Cause-effect diagram per company

Below, the CE diagram for each company will be showed and described which is based on the lessons learned from the interviews.

Company A

The cause-effect diagram of Company A is presented in Figure 32 on the next page. The main problem of Company A is the increase in costs. This problem is caused by two factors; high illness percentage among their employees due to the occurrence of the pandemic, and a low productivity. The low productivity is caused by insufficient reliability in operations. This insufficiency is caused by several factors, which are explained below.

We first go back to the beginning of the cause-effect diagram. The occurrence of the Corona pandemic caused some restrictions that are created by the government. These restrictions have caused four different effects. Due to the restrictions, some countries went in lockdown, and borders were closed. Due to the closed borders, there was too low available capacity of transport modalities. For instance, for many airlines it was not economically viable to fly which caused a big loss of (belly) freight capacity. Furthermore, it took more time for trucks to cross the borders, and sometimes they were even not allowed to cross the borders. Because of this, the warehouses of the integrators of Company A became overloaded. Furthermore, because of the Corona restrictions, consumers cannot leave their houses which led to higher online sales which also caused overloaded warehouses of the integrators. This resulted in the integrators not coming to pick-up packages/containers in the warehouses of Company A, which in turn caused an overload at Company A’s warehouses. Additionally, because of the 1.5 metres restriction, many employees had to work from home resulting in a stop of physical meetings with customers. Besides that, the 1.5 metres restriction caused that Company A’s warehouses were overloaded because the employees could work less efficiently. Moreover, during the Corona crisis, it became clear that there was a lack of information sharing from the customer side. This caused too low visibility in the supply chain which made it difficult to plan. Therefore, Company A did not know how many containers they could expect causing overloaded warehouses. During the pandemic, there was a high illness percentage amongst the employees, which leads to insufficient reliability in operations. Due to the working from home and the Corona restrictions, it was difficult to train new personnel causing insufficient reliability in operations as well. The insufficient reliability in operations is also caused by the fact that sub-contractors might not want to work with Company A anymore. Company A scaled down sub-contractors which may lead to decreased trust in working together with Company A. This scaling down is caused by a decrease in consumer demand due to the occurrence of the Corona crisis and the fact that Company A sticks too much to their business model.

The company culture of Company A focuses on an asset-light strategy. This means that they do not own a lot of assets, but make use of sub-contractors. This caused a problem during the Corona crisis; they became too dependent on integrators, other local logistic service providers and labour agencies. The integrators, such as DHL and UPS, and the labour agencies, had their own problems in to the Corona crisis. Also the logistic service providers were busy with their own processes. This in turn caused that the reliability of the operations of Company A were affected. Another aspect that was noticed because of the asset-light strategy, was that the company sticks too much to their business model during the Corona crisis. The consequences of this are explained above.
Company B
The cause-effect diagram of Company B is presented in Figure 33 below. The main problem of Company B is the lower margin. This problem is caused by one factor, namely higher production costs. Company B does everything to keep the revenue stable. Extra production costs are made, which has resulted in a decrease in margin. The higher production costs are caused by two different factors; inefficiency in production process and higher transportation costs. First, the inefficiency in production process is described below. Thereafter, the causalities of the higher transportation costs are explained. The inefficiency in the production process is caused by five different causes.

- First, less people are allowed to be in the Clean Room due to the Corona restrictions, like the 1.5-metre rule, which again is caused by the occurrence of the pandemic. The 1.5-metre rule says that people must be at least 1.5 metre distance of each other.
- Second, since there may be less people in the clean room, and the working from home caused by the Corona restrictions, it is very difficult to train new personnel.
- Third, because of the low supply that is caused by several other reasons which will be explained later, there is too low reliability in the supply.
- Fourth, the too complex and uncertain production management, which is caused by the too low reliability in supply and possible uncertainty about demand. Both factors are described below.
- Finally, the last cause is the rework. During the Corona crisis, Company B implemented one critical component in multiple machines to test them. It took extra time to place these components in a machine and then remove them again.
The higher transportation costs are caused by one reason. To explain this further, we go back to the beginning of the cause-effect diagram. Company B is very dependent on one transport modality, namely air. Due to the Corona crisis, it was not economically viable to fly for many airlines. Because of this, the capacity of the belly freight reduced. This reduction caused higher transportation costs.

Most of the components that Company B uses in their machines are single sourced. As discussed in the lessons learned, this is a risk for Company B since they are very dependent on certain suppliers who are the only ones that can produce these components. Especially, when disruptions hinder the smooth delivery of supplies, this dependency on suppliers causes too low supply levels for Company B. For example, closed borders and lock downs could hinder the delivery of supply. Moreover, Company B slowly reacted in helping their suppliers in the Semicon industry. The Semicon is a very important industry, and therefore the government made the exception for this industry to resume the transportation of supplies. Company B did not communicate this directly to their suppliers, and they did not make clear to the government that their business is critical, which caused the low supply of materials. The too low supply level caused too low reliability in supply.

Due to the Corona crisis, there was a drop in the consumer trust, which resulted in postponement of spending money. This could cause a decrease in the demand of Semicon in the upcoming months/years. In turn, this possible decrease of demand could cause possible uncertainty about demand in the future.

![Figure 33: Cause-effect diagram Company B](image-url)
Company C

The cause-effect diagram of Company C (and Company Ca) is presented in Figure 34 on the next page. The main problem is lower profit margin. This problem is caused by two factors; high revenue drop and the fixed execution costs. First, the causalities of the fixed execution costs are explained. Thereafter, the causalities of the high revenue drop are explained.

Company C has a lot of fixed personnel and fixed assets. These too high fixed assets as well as the too much fixed personnel caused fixed execution costs, whether the operations are running or not.

To explain the causalities of the high revenue drop, we go back to the beginning of the cause-effect diagram. The occurrence of the pandemic caused some restrictions that are created by the government. These restrictions have caused four different effects;

- Many employees had to work from home. This led to a low responsiveness and resilience.
- Consumers could not leave their houses, which led to a drop in (Automotive) demand.
- Production facilities had to shut down, which caused a drop in the (Automotive) production.
- Some countries went in lockdown, and borders were closed. Due to the closed borders, there was a drop in the (Automotive) production.

The occurrence of the pandemic caused a lack of consumer trust. An example of this is the uncertainty about keeping their job in times of crisis. This makes them reluctant to spend money. Besides this, there are consumers that are already laid off because of the pandemic. These people can spend less money. Both factors cause a decrease in the (Automotive) demand.

The drop in (Automotive) demand together with the shutdown of production facilities and closing borders, caused a drop in (Automotive) production. Furthermore, the drop in (Automotive) demand led to overcapacity in the road transportation sector, because there is less volume to transport. Because of the overcapacity, there is an increased competition that leads to price wars amongst logistics service providers. The price wars eventually lead to a high revenue drop, because Company Ca and Company C had to lower their prices.

Because of the crisis, Company Ca realised even more that their information system was outdated and inflexible. Moreover, it became clear that there was a lack of information sharing from the customer side. Both caused too low visibility in the supply chain which in turn caused low responsiveness and resilience. Company Ca stated that the future is so uncertain, that they have no plan for the future. However, the interviewees mentioned that maybe the Corona team is working on a plan, but the interviewees were not aware of this.

Company Ca has a small industry portfolio which makes them very dependent on the Automotive industry. The Corona crisis showed that the Automotive industry is vulnerable. Due to the high dependency on this industry, there was a big drop in the demand of Company C and Company Ca. This drop is also caused by the drop in the (Automotive) production and demand. The volume drop in Company C and Company Ca demand together with the increased price competition, caused a high revenue drop for the whole company. In the end, the high revenue drop and the fixed execution costs led to lower profit margin.
The cause-effect diagram of Company D is presented in Figure 35 below. The main problem of Company D is the too complex and uncertain production management. This problem is caused by five factors:

- Too high uncertainty about demand
- Too difficult training of personnel
- Decreased level of collaboration
- High illness rate due to the occurrence of the pandemic
- Too high uncertainty about supply

Each factor will be explained in a separate paragraph below.

Due to the Corona crisis, the trust of consumers decreased which led to many consumers stop spending money. The postponement of spending money could cause a decrease in the demand of Semicon in the upcoming months/years. This possible decrease of demand could result in uncertainty about demand in the future. This uncertainty could cause higher complexity and uncertainty in production management. Besides that, the too high uncertainty about demand is caused by two other factors; too less interaction with customers and too dependent on a few markets. During the Corona crisis, Company D did not spend time on interaction with their customers. Meetings with key customers could not be done physically anymore, which implied operational challenges in making agreements. Furthermore, Company D operates in Healthcare and Semicon, which implies that they are dependent on both markets. When one of these markets will be hit, Company D will have a big problem.

The occurrence of the Corona pandemic caused restrictions that are created by the government. An example of such restriction is the 1.5 metres rule. Because of this restriction, there was too little workspace at the office of Company D. This in turn caused that a lot of people had to work from
home. Usually, Company D visited their customers on a regular basis, however this type of interaction was not allowed anymore because of the working from home, which caused a decreased level of collaboration. Furthermore, because of the working from home and the Corona restrictions, it was difficult to train new personnel. The difficulty of training new personnel as well as the decreased level of collaboration both caused too complex and uncertain production management.

The last factor of the main problem of Company D is the too high uncertainty about supply. This factor is caused by two factors; too less interaction with suppliers and too low supply. During the crisis, Company D had too less interaction with their suppliers, because physical meetings were not allowed due to working from home. Company D, but also their suppliers, were focussed on their own operations instead of interfering with each other. Too low supply is caused by five factors; inadequate material criticality assessment, inadequate supplier risk assessment, geographically dispersed suppliers, single sourcing and reduction in belly freight capacity. The criticality levels of certain components were not accurate. During the interview, the example was mentioned that a component that Company D uses was scaled at a low criticality level. The specific component is made in America, shipped to India to put the wires on the waver and then shipped to Mexico to clean it before it is shipped to Company D in the Netherlands. Because of this complexity, this component could not be delivered during the Corona crisis. This resulted in Company D noticing that this component was more important than they initially thought. So, the criticality level of this component should have been higher. What also became evident during the Corona crisis, is that in some cases the supplier risk assessments were not accurate enough. The reliability of suppliers dropped from 90% to 70%. This caused a low supply. Furthermore, the suppliers of Company D are geographically dispersed around the world. During the lockdowns, this was a big disadvantage for Company D and caused a low supply. Most of the components that Company D use in their production process are single sourced. This is a risk for Company D since they are very dependent on certain suppliers who are the only ones that can make these components. This dependency caused too low supply levels. The last cause of the too low supply is the reduction in belly freight capacity which in turn is caused by the too high dependency of Company D on one transport modality, namely air. During the Corona crisis, the passenger flights were not economically viable to fly. This caused that the capacity of the belly freight reduced which caused that the supply of material was lower.

Figure 35: Cause-effect diagram Company D
Appendix D: Survey template and survey results

The survey can be found by using the link below. This will open a Google Forms document with all the questions and answer possibilities. It should be noted that most questions are linked to other questions, so a respondent will only get questions that are relevant based on the answers given to previous questions.

https://docs.google.com/forms/d/117Wy17Po9j9UcVyzIolhTHa6V4SJbqONb_8LiS_pguA/edit?usp=sharing

A description of the survey results can be found below.

**Demand levels**
The demand levels of 7 out of the 10 companies have decreased, see Figure 36 below. The main reasons for this reduction are that customers were not able to buy products or use services due to lockdown, closing of borders, governmental restrictions and production issues at customers. This decrease in demand is also found in most of the interviewed companies, with the exception of one company. That company experienced a higher demand of its current customers and even got additional customers. This was because of the struggling of their competitors during the crisis. It became clear in the survey results that 57.1% of the companies who experienced a decreased demand level are almost recovered. 28.6% of the companies indicated that their demand levels are hardly recovered. No company indicated that they are already fully recovered. Looking at the expected recovery time of companies with decreased demand levels, 57.1% of the companies indicate that they expect a recovery time of 2-4 months. 14.3% of the companies expect that there will be no full recovery at all.

![Figure 36: Survey question “What happened to your demand levels?”](image)

**Production levels**
Figure 37 shows the results for the question related to the production levels. 30% of the companies have filled in ‘Not applicable’. This implies that 7 out of 10 companies do have production processes. From these 7 companies, 4 companies indicated that there was a decrease in their production levels. The main reasons are a decrease in demand levels and lockdown at the production site. Two companies in the DASCOVIMI consortium did not discover a decrease in their production levels, so this result of the survey is different from the finding of the interviews. Nonetheless, the results of the survey show that, for the 3 out of 7 companies that experienced a stability or increase in production, the main reason is buffer inventory. This is in line with the findings of the interviews.

![Figure 37: Survey question “What happened to your production levels?”](image)
Supply levels
In Figure 38 below, it can be seen that 20% of the companies have filled in ‘Not applicable’. This means that 8 out of 10 companies have suppliers. The results of the survey show that 4 out of those 8 companies indicated that they had a decrease in their supply levels. The main reason is lockdowns at the suppliers’ sites. This causality is also found in the interviews. Furthermore, other results of the survey show that 1 out of those 4 companies is hardly recovered and the other three companies are almost fully recovered. Looking at the recovery time of companies with decreased supply levels, 50% of them expect a recovery time of 4-6 months. The other 4 companies experienced a stability or increase in their supply levels. This is mainly caused by the fact that their suppliers lost other customers which implied that they could deliver more to them.

Impact on warehouse
From the 10 companies that filled out the survey, 8 companies have their own warehouses or facilitate operations in the warehouses of their customers. In total, 7 out of the 10 companies faced a high or mediocre impact on the operations in the warehouses during the Corona crisis, as can be seen in Figure 39 (Left). The main reasons are the Corona restrictions and measures, lower inbound levels, and lower outbound levels. The companies were asked if they experienced this impact as negative or positive, and all 7 companies answered that they experienced this impact on their warehouses as negative. This negative impact is in line with the findings of one of the interviews.

Transportation modalities
In Figure 39 (Right), it can be seen that 50% of the companies indicated that there was a high or severe impact on their transportation caused by the outbreak of COVID-19. The main reasons are changes in frequency of transport movements, and the Corona restrictions and measures. 90% of all companies experienced the impact as negative. This finding complements the results of the interviews. Two companies in the DASCOVIMI consortium also experienced a reduction in the availability of transportation, especially the capacity of belly freight heavily decreased.
Lead time
In the survey, there are two questions related to the lead time; the lead time between the supplier and the company involved, and the lead time between the company involved and their customers. Looking at the total lead time, 80% of the companies indicated that their lead time is increased. None of the companies saw a decrease in the lead time. The main reason for the increase in lead time between the company and their suppliers is a reduction in both supply levels and transportation levels. The main reason for the increase in lead time between the company and the customers is a decrease in transportation levels. One interviewed company also discovered an increased lead time in delivering spare parts at customer sites due to a reduction in the availability of belly freight capacity. Based on this example, it can be seen that the results of the survey complement the findings of the interviews.

Visibility
Regarding the visibility in the supply chain, the survey results are in line with the outcome of the interviews. In Figure 40 below, it can be seen that for 60% of the companies there is visibility from their side, and 30% indicate that there is an increasing need in visibility. During the interviews with the four consortium companies, it also became clear that the information sharing is mostly from their side and also that there is an increasing need for visibility. Also the type of information that is shared with supply chain partners is similar for both the survey and the interviews. Mainly forecast data are shared by the companies with their supply chain partners, and the supply chain partners mainly share their supply plans with the companies. It is interesting to see that 60% of the companies that filled out the survey are (rather) unsatisfied with the current level of visibility, and 80% want to increase the visibility in the supply chain.

Supply chain strategies
Concerning the supply chain strategies of companies, there is an interesting difference in the results of the survey and the interviews. In the interviews, there were only two companies that already had a contingency plan in place before the disruption happened. However, in the survey it came forward that 70% of the companies have multiple strategies in place for when a disruption happens. They either have a backup strategy for when a disruption occurs, or they have multiple strategies in place for different situations (including disruptions). 60% of the companies that filled out the survey indicated that they are planning on adding extra strategies to prepare themselves better for a future disruption.

In the survey, 70% of the companies indicate that they have a supplier sourcing strategy, and of this 70%, 57.1% say that they are not planning on changing this strategy due to the Corona crisis. The strategies that are mentioned most are dual sourcing, alternative sourcing, local suppliers and global suppliers. The companies that do plan to change their strategy indicate that they are planning to regionalize, move closer to demand and make more use of dual sourcing instead of single sourcing of critical parts.
70% of the companies that filled out the survey indicate that their current transportation strategy worked fine during the crisis, so there is no need for a change in strategy. This is in line with the results from the interviews that are conducted. The companies that filled out the survey that do want to implement a change, say that it would be part of their daily routine, rather than a back-up plan only for when a disruption occurs.

Planning & forecast models
The results of the survey show that there is a change in the frequency of S&OP execution before and after COVID-19. Before, 50% of the companies executed their S&OP monthly, and 20% weekly. Currently, this is 40% monthly and 30% weekly, implying that one of companies is checking their planning more frequently. Also, 70% of the companies say that there is a need for change in their current forecast model. Most of them say that this will be done by having more informal communication and using other forecast methods. Other examples of changes in forecast models can be seen in Figure 41. Looking at inventory management strategy, both in the interviews and in the survey, it came forward that the companies are satisfied with their current inventory management strategy.

Flexibility
From the interviews, it became clear that most of the companies were rather flexible in terms of scaling up or down assets, and/or in terms of the production process. The survey showed mixed results concerning flexibility; 50% of the companies indicated that they are not that flexible and the other 50% indicated that they are (very) flexible.

Financial monitoring
There are a lot of financial parameters that a company can monitor. All companies indicated that they monitor Revenue, Cash Flow and Net Profit. Most companies also monitor Gross margin. Before the Corona crisis, 80% of the companies monitored financial parameters on a weekly or monthly basis. Because of the Corona crisis, 50% of the companies changed the frequency of monitoring financial parameters to be able to make better decisions based on that financial information, as can be seen in Figure 42. For the companies that indicated that they have changed the frequency of monitoring financial parameters, the period of monitoring became shorter: instead of monthly and weekly, the monitoring changed to weekly and daily respectively.
The Corona crisis impacts companies in many ways, also the financial performance of a company. From the 10 companies that filled out the survey, 80% saw a decrease in their revenue during the Corona crisis. This decrease in revenue varied between 6% and 30%. Looking at the cash flow, half of the companies indicated a decrease in cash flow which differed between 10% and 25%. 40% of the companies did not see a change in cash flow. There were 4 companies that experienced a drop in their margin, fluctuating between 5% and 30%, and 5 companies that indicated no change in their margin. The results of the survey show that 80% of the companies did not see a change in trade credit policy or short-term debt. Looking at the costs, 40% of the companies saw a decrease in costs and 50% indicated that they did not see a change in costs. 10% (one company) saw a small increase in their costs. There was 1 company that profited from the Corona crisis. It experienced an increase in revenue, an increase in margin and was able to extend its trade credit by 10 days.

The results of the survey show that half of the companies that filled out the survey have an already recovered financial position. Looking at the expectation about the recovery time of the other half of companies that have a not recovered financial position, 60% expects the recovery time to be more than 6 months. There are various actions that a company can take to financially recover. Most companies indicated that they reduced travel expenses and scaled down on employees.

**Collaboration**

In times of a supply chain disruption, supply chain partners can support each other. In Figure 43, it can be seen that 6 out of the 10 companies indicated that they are willing to financially support a partner in their supply chain when they are affected by a disruption. From those 6 companies, 2 companies have actually supported a supply chain partner during the Corona crisis. During the interviews, the companies also indicated that they are willing to help important supply chain partners when needed, but that the situation did not occur during the Corona crisis.

![Figure 43: Survey question “Will you financially support a partner in your supply chain when they are affected by a disruption?”](image)

**Internal and external information**

Having the right internal and external information can help the (fast) decision-making process during a disruption. The survey results show that 50% of the companies think that they did not miss any information that could have helped in the decision-making process. However, it is possible that they are simple not aware of that. The companies that indicated that they missed information, mainly missed external information regarding forecast, planning and stock level information. Also during the interviews, it was mentioned several times that there was an increasing need for certain external information. There were no companies that introduced new (non-financial) KPIs during the Corona crisis, for both the companies that filled out the survey and the companies that were interviewed.

**Working from home**

The Corona crisis and related measures taken by the governments, made it necessary that employees had to work from home instead of at the company’s facility. All companies that filled out the survey indicated that it was possible to work from home (for certain departments). Even though there are
advantages, working from home can also lead to problems. Less contact with colleagues and psychological or health issues are problems that are mentioned most by the companies that filled out the survey. This is in line with the findings from the interviews.

### Illness

It can be expected that a pandemic such as the Corona crisis has an influence on the illness percentage of companies. The survey results concerning illness percentage are presented in Figure 44. It can be seen that 40% of the companies did not see a change in illness percentage. 30% experienced an increase in illness percentage which varied between an increase of 1% to 20%. The other companies experienced a decrease in illness percentage fluctuating between 4% and 50%. These results of the survey are in line with the findings of the interviews, where most companies indicated that there was either no change in illness percentage or an increase. One of the interviewed companies indicated that now that their illness percentage is recovered, they even see a decrease in the illness percentage because people are less likely to call in sick when they are working from home.

![Figure 44: Survey question “Has there been a change in the illness percentage due to the Corona crisis?”](image)

### Hiring procedure

8 out of 10 companies have not laid off any employees during the Corona crisis. However, 60% of the companies indicated that there was a (temporary) stop on hiring new employees. Both findings are also mentioned in most of the interviews. Furthermore, 40% of the companies that filled out the survey, indicated that they encountered problems with the training of new employees. The problems that companies encountered regarding the training of new employees were mainly caused by working from home. This is in line with the interview findings.
Appendix E: Stock prices of different market indexes

Figure 45: Stock prices of market index in the Netherlands

Figure 46: Stock prices of market index in France

Figure 47: Stock prices of market index in the United States
Figure 48: Stock prices of market index in Germany

Figure 49: Stock prices of market index in Switzerland

Figure 50: Stock prices of market index in Great Britain