

# THE SUPPLY CHAIN DISRUPTION MANAGEMENT MANUAL

RESULTS FROM THE DASCOVIMI PRESSURE COOKER PROJECT

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**Authors** prof. dr. Ton de Kok, Edwin Wenink MSc, dr. Shaunak S Dabadghao, dr. Laura Genga, Ravi P Ranjan PhD, Valerie Geelen MSc, Marliek Raadsheer MSc, Romy Olislagers BSc - Eindhoven University of Technology\*

**Title** The Supply Chain Disruption Management Manual

**Design** Michelle Haak Miesart

**Final editing** Liesbeth Brügemann TKI Dialog

\* prof. dr. Ton de Kok has been general director of Centrum Wiskunde & Informatica (CWI) since October 2020.

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## MANAGEMENT SUMMARY

**The COVID-19 pandemic has adversely affected every economy in the world. Not only has it changed the way we work and travel, it also heavily disrupted international supply chains and networks.**

The DASCOVIMI<sup>1</sup> research project aimed at giving insights into how a pandemic impacts organisations in the supply chain (discovery), but also how they should react and recover (recovery) and take preventive measures based on the lessons learned during the current recovery process for the future (redesign).

In this research project, we were able to obtain high-level insights into how the COVID-19 pandemic has impacted the manufacturing industry, as well as the logistics sector. Four firms were studied in detail and we conducted large scale surveys with ESCF members to see the impact across other industries as well.

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 government rules and decisions 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 families as well as firms, but did not cause severe operational problems for jobs outside the production, warehousing and transportation "shop floor domains". Immediate ICT support was necessary but almost in every case given and people had to adapt to the new normal of working online.

Of the 4 firms we studied in detail, we observed that 3 of them were not severely hit by the pandemic. A

few saw dips in demand and revenue but 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. Flexibility and the ability to quickly adapt to disruption is 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.

We developed a Cause-Effect (CE) diagram that describes the causal chains between the pandemic occurrence and its impact on revenue, costs and thereby on profit, which eventually determines the viability of a company and the supply chains it participates in. The CE diagram serves two purposes. It can be used as a tool to help understand what has happened in the supply chain, and its propagation in the chain knowing when countries and regions were locked down. It also serves as a framework to support the identification of measures to be taken to recover from the pandemic and measures that can mitigate the impact of the pandemic at acceptable investment levels. In that way an effective pandemic management expert system can be created.

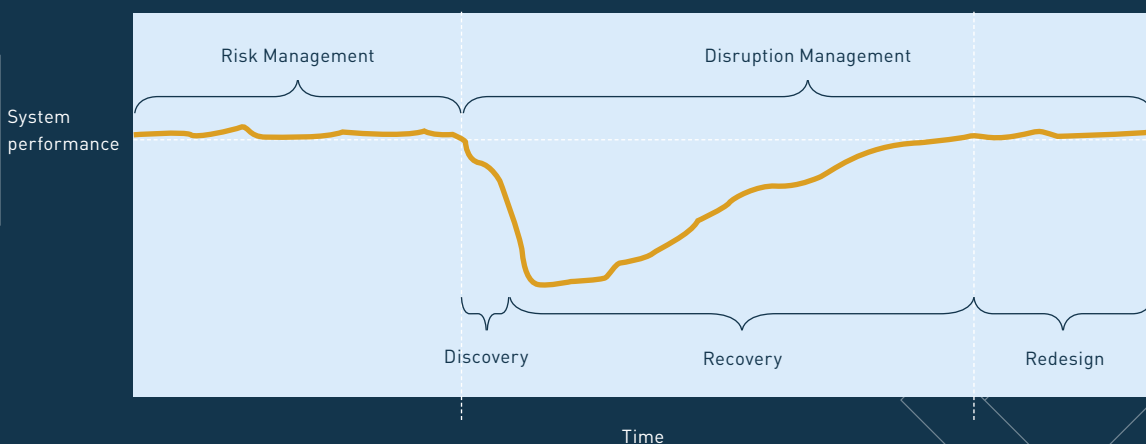


Figure A. Time-series of evolving disruption [Macdonalds & Corsi, 2013]

1. DASCOVIMI is an acronym and stands for 'Disruption Analysis of the SC due to Corona Virus, based on actual information, with focus on Manufacturing industry'.

Applying the CE diagram in this way, we have been able to propose a number of generic recommendations, in the different stages, that provide guidance when meeting the challenges posed by a major supply chain disruption:

#### Discovery

- Critically analyse and monitor internal processes and external information.

#### Recovery

- Not solely focus on its internal business, but also monitor suppliers, customers and competitors to improve recovery.
- 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.
- Focus on employees during a disruption, where employees are being informed and involved, and where (informal) social contacts are being retained.
- 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.

#### Redesign

- Have a contingency plan in place for when a disruption happens.
- Evaluate its 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.
- Evaluate components, processes and management, how they changed during the crisis, and decide whether permanent changes need to be made.
- 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 (insurance) contracts to be sure that you have reliable (insurance) partners with reliable contracts.
- Evaluate sourcing strategy, taking into account the global impact of a pandemic.

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# THE CONTEXT

## 1.1 THE IMPACT OF CORONA PANDEMIC

Coronavirus 2019 (COVID-19) is not the first pandemic humanity has witnessed. Millions of lives have been lost due to pandemics like Black death (1331-1353), Third plague pandemic (1855), Spanish Flu (1918-1920) and HIV (1981-present). What makes COVID-19 different is its high transmission rate and disproportional effects on older people with underlying conditions (Wo and McGoogan, JAMA, 2020). Without immediate containment measures (such as social distancing) of COVID 19, the virus is bound to spread exponentially (Maier and Brockmann, Science, 2020) leading to an enormous number of infections. So, the first understanding of the government think-tanks and healthcare experts was to make this spread sub-exponential and flatten the curve. The idea was to delay the spread and reduce the peak burden on healthcare (Figure 1). As a result, **'lockdowns in varying capacities'** became one of the primary regulatory and preventative measures to contain the spread of Coronavirus.

The lockdowns began with three big consequences:

- Confining millions of people to their homes,
- Large scale travel/movement restrictions and
- Business shutdowns.

As a result, the lockdown led to a halt in economic activities and a massive decrease in consumer spending (as consumption was restricted to necessary items). This forced the global economy into a deep recession. The World Bank reported the

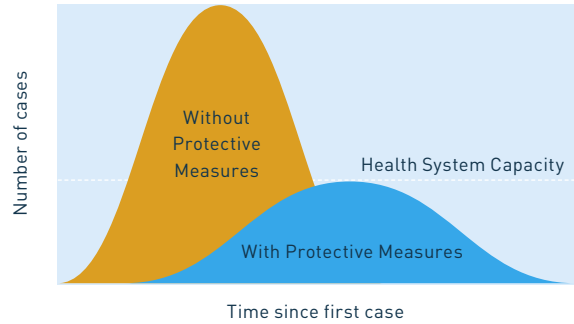


Figure 1. Illustrations for Flattening the Curve (New York Times, 2020)

recession due to COVID 19 as the fastest and having the steepest downgrades (Figure 2). The immediate response of the policy makers across the globe was to focus on strengthening health services and bringing an economic stimulus package to revive their respective economies. For example - the US House of Representatives announced a \$2.2 Trillion stimulus package, and the German government announced a 130 billion recovery package for Coronavirus impact.

The above description brings out the macro-level perspective of the impact of COVID-19 on economies across the globe and initial government responses. However, the real challenge in front of business leaders of today is to combat and recover their operations from supply and demand disruptions caused by lockdowns, travel restrictions, and new social norms. Our study focuses on understanding the disruption process and impact to supply chains

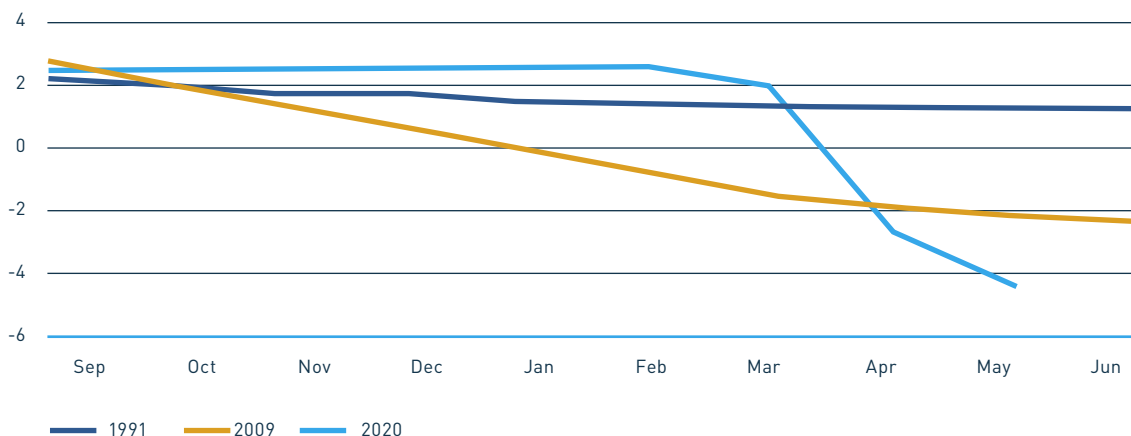


Figure 2. Consensus forecasts of global GDP (percent) (The World Bank, 2020)

with a specific focus on the manufacturing industry. Current studies suggest that the global supply chain losses, due to COVID-19 lockdowns, depend on – number of countries imposing restrictions and duration of lockdowns (Guan et. al, Nature Human Behavior, 2020). So, it is pertinent to understand:

- What happens to supply chain processes (what impacts a firm's performance) under different lockdown measures?
- How should firms respond to this disruption and what should be their recovery action plan going ahead?

The project DASCOVIMI aims to answer these two questions comprehensively. DASCOVIMI stands for **“Disruption Analyses of the Supply Chain due to Corona Virus, based on actual information, with focus on Manufacturing Industry”**. The primary context and data source of our study are the interviews/survey conducted in the Netherlands and Europe. To further motivate the relevance of this study, the data on the average daily output generated by Dutch manufacturing showed that the output in May 2020 was 12.5% less when compared to this output in May 2019 (Central Bureau of Statistics, Netherlands). The objective of our project is to suggest disruption recovery strategies for manufacturing firms so that its implementation could lead to an improved output.

Our research in the manufacturing industry, together with an extensive study of literature on supply chain disruptions, their impact and possible routes to recovery and business as usual, has led to insights and instruments that apply beyond the manufacturing industry. We believe that our generic findings can be of value to all supply chain

management professionals confronted with a major disruption of their businesses.

## 1.2 DISRUPTION IN THE MANUFACTURING SECTOR

The focus of this research is the manufacturing industry. Therefore, it is useful to look at the overall impact on the manufacturing industry. The German statistical information source ‘Destatis’ is consulted to gather information regarding the production in the manufacturing industry. It can be seen in Figure 3 that there is a big drop in production in big countries such as Germany and France. This is in line with the European average production. In Italy, where there was a big outbreak of the virus, there was an even higher drop in production. In the Netherlands however, it can be seen in the Figure 3 that the impact on the production was lower.

The Corona pandemic has a major impact on supply chains worldwide. 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 industry participates. These mutual dependencies eventually have resulted in Dutch companies coming to a hold because of suppliers not delivering parts or losing the major part of their revenues as market demand dropped dramatically or because 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.

As soon as the pandemic is under control, the current measures inhibiting starting production and sales will be (gradually) alleviated. However, starting up production in supply chains that are in total disarray is not a straightforward task. The current situation is far worse than after the financial crisis, with far more links (companies) in the supply chain

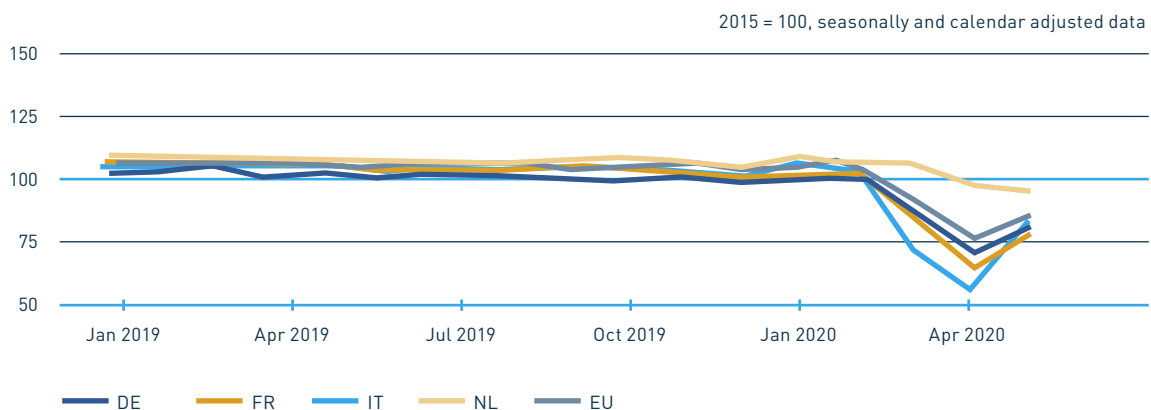


Figure 3. Production in the manufacturing industry (Destatis, 2020)

affected and with far more markets dropped down within a month period.

Starting up implies that we need scenarios about the market recovery over the next months to two years in various sectors. These market scenarios drive the need for products and parts for the months after start-up. In turn, these needs drive the need for resources, i.e. workers, equipment, and logistics services. And all activities and transactions starting up require cash. And starting up 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 that affects production capacity as well as (public) transportation capacity to move workers from home to production and distribution sites.

As supply chains are global, starting-up supply chains are facing different Corona regulations in different countries with different evolution paths. As many companies have a vulnerable cash position due to drops in revenues and continuing payments to employees, starting up supply chains is constrained by cash availability.

Innovative academic thinking and insights are necessary to overcome the challenges mentioned above. Parsimonious modelling to generate qualitative insights does not suffice. Operational decisions in global supply chains are taken real-time, daily, weekly and monthly. Under major disruptions, frequency of supply chain alignment decisions needs to go from monthly to weekly. Thus, there is a need for decision support that enables information extraction from data stored around the globe and in the cloud. Next, decisions must be derived from this information, within seconds, enabling interactive decision making. And finally, decisions taken must be deployed across the supply chain to the shop floor.

The DASCOVIMI project findings provide directions for development of the necessary supply chain innovations: what, where, and when. We found that qualitative research, involving supply chain professionals and academics, has been an effective tool for development of a holistic framework that provides the necessary guidance. Thus, further research can be focussed on the right challenges, moving from descriptive analysis, to predictive analysis, and eventually to prescriptive decision support.

### 1.3 THE OBJECTIVES IN DETAIL

The DASCOVIMI project aims at the development of

1. A model-based research approach that can be applied for analysing globally disrupted supply chains from both supply chain perspective and individual company perspective, and from both shipper and service provider perspective.
2. Qualitative insights into the relevant aspects of effectively and efficiently starting up supply chains after a pandemic or similar global supply chain disruption.
3. A SCM and Logistics research agenda concerning starting up supply chains after a pandemic or similar global supply chain disruption.

The project results are translated into this Supply Chain Disruption Management manual<sup>2</sup>.

The project started on the 15<sup>th</sup> of May 2020 and finished on the 1<sup>st</sup> of October 2020.

We executed this research with 4 consortium members. These companies provided the researchers with both facts and perceptions on actual market and supply chain developments in the course of the project, in combination with company transactional data.

### 1.4 RELATION TO TKI DIALOG'S INNOVATION THEMES

The project has been funded by Dinalog and the European Supply Chain Forum (ECSF) at TUE. We aligned the project objectives with the Dinalog innovation themes:

#### 1. Supply Chain Coordination

Starting up supply chains after a pandemic requires (global) supply-chain-wide coordination, as demand, production, logistics, and finance can all be constraining supply chain partners in different ways, all affecting the flow of goods from suppliers to consumers and users.

#### 2. Data driven logistics

Data capture and data analysis is paramount for effective and efficient supply chain start-up. The data capture is real-time or daily due to the expected dynamics and volatility of processes involved. Frequent feed-back of the current supply chain state towards all decision makers involved, enables coordination of task execution across the supply chain.

<sup>2</sup> A preliminary version of the manual has been set up around the end of July. This version was based on the qualitative insights obtained from the structured interviews. The reason for creating this preliminary version was the expected urgency of providing results of our research to the industrial members of our consortium and their supply chain partners outside the consortium.



**3. Human Capital**

Many companies have no experience with recovery from a pandemic of this magnitude. Employees in SCM and Logistics must be trained to acquire the knowledge needed. The project delivers material that can be used for this training.

The project applies to supply chains (i.e. shippers), as well as to nodes and corridors (i.e. logistics service providers). The research is characterized as (model-based) qualitative empirical research and paves the ground for experimental development of knowledge and tools for supply chain recovery from a pandemic or similar major global supply chain disruption.

**1.5 DISRUPTION MANAGEMENT LITERATURE**

There are different types of risks that a company can encounter. Wu, Blackhurst & Chidambaram (2006) classify them as internal or external, and the degree to which they are controllable. Internal risks are those that are usually under the control of the company, whereas external risks are beyond the company’s control (El-Sayegh, 2008). The Corona pandemic can be seen as an external risk, because the company does not have control over it.

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 a supply chain disruption: “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, Glasen & Straube, 2017; Revilla & Saenz, 2017; Tse, Matthews, Tan, Sato & Pongpanich, 2016).

Supply chain disruption 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 dampen 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, Saenz & Koufteros). 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 4).

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. From our literature research we found that resilience is based on four aspects: 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 to be not 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).

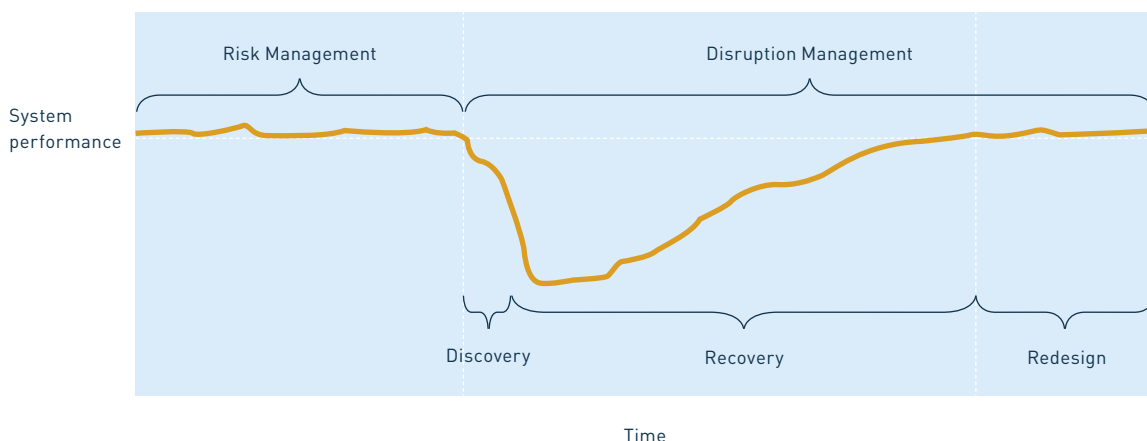


Figure 4. Time-series of evolving disruption [Macdonals & Corsi, 2013]

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 needed.

In disruption management there are two main strategies that can be used, namely 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, Feisel, Hartmann, Giunipero, Saenz & Koufteros, 2015). A proactive strategy often facilitates an easier and quicker response to the disruption, since visibility should lead to early warnings (Grötsch, Blome & Schleper, 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 (Hohestein et al., 2015).

Furthermore, there are a number of trade-offs that need to be made in disruption management. The ones that will be highlighted here are supplier selection, inventory management and redundancy vs 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 5. It is also possible to make use of dual sourcing, which is making use of two suppliers. When combining a foreign and local supplier, 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 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 by 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

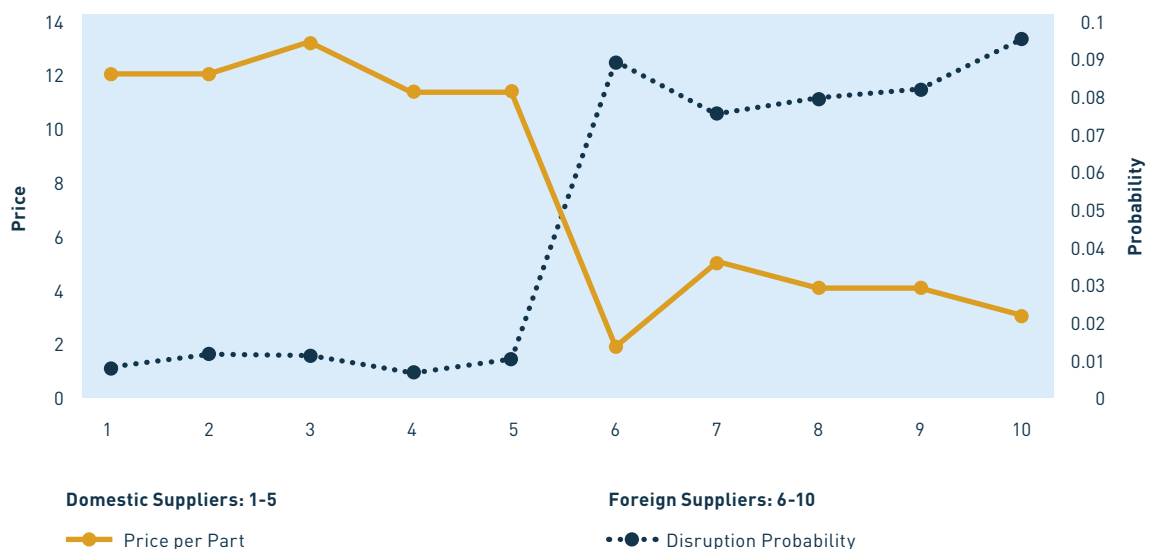


Figure 5. Comparison domestic suppliers vs foreign suppliers in terms of price and disruption probability (Sawik, 2014)

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 seen only 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 often accompany 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, Stevenson, Busby & Zorzini, 2015).

Our literature makes clear that trade-offs in disruption management are about balancing short-term goals and long-term goals. As major disruptions, like a pandemic, occur infrequently, investments in proactive disruption management, creating agility, these investments do not pay off as long as the major disruption does not occur. This may put investments in agility and resilience under pressure.

### 1.6 RESEARCH METHODOLOGY

This section describes the main steps that are taken in this research project. Given the “pressure-cooker” timeline and the ambitious objectives of the project, we decided to employ a business research method, rather than a scientific research method. This implied that we used the partner companies to elicit experiential knowledge on the impact of the pandemic and the why and how of the actions taken to mitigate its impact and start recovery.

It is important to note that the business research method builds on the expertise of the scientific researchers involved. We stated earlier that we apply a model-based empirical research approach. To clarify this further, the research group involved has contributed substantially to scientific literature on Supply Chain Management over the last three decades. Starting from real-life supply chains at companies like Philips, Océ-Canon, Unilever, and ASML, quantitative models have been defined,

analyzed and subsequently applied to improve these supply chains, in particular to reduce capital employed while improving customer service. A large number of MSc projects has enabled the knowledge transfer. Show case projects like the Collaborative Planning project at Philips Semiconductors (De Kok et al. (2005)) have built extensive knowledge on how to cope with extreme volatility in global supply chains. Over the last decade many projects have been executed on various links in the high-tech supply chain, yielding further scientific and professional knowledge on state-of-the-art SCM in manufacturing. This enabled a kickstart of our project in the manufacturing industry.

As a first step, the existing SCM knowledge was further extended with an extensive review of Supply Chain disruptions literature, as already discussed above. This enabled the formulation of a questionnaire that was used for structured interviews with a number of representatives from the partner companies. We also used the questionnaire for an online survey among the members of the European Supply Chain Forum. The results of the structured interviews were summarized in a SWOT (Strength, Weakness, Opportunity, Threat) analysis for each of the partner companies. The SWOT analysis was validated with each of the companies.

The SWOT analysis served as the basis for a major step in our research: the development of a Cause-Effect diagram that provides a holistic view of the causal relations between aspects of relevance for discovery, recovery and redesign of the transformation processes and business processes in the supply chain. First we created a CE-diagram for each partner company, as each of the companies experienced different impact on their supply chains. Again we validated each CE diagram with the partner company representatives.

From the four company CE diagram, we created an integrated generic CE-diagram using a number of workshops to stimulate out-of-the-box thinking. Each of the causes/symptoms was defined carefully, i.e. unambiguously. Likewise, each of the causal relationships between cause and effect was described. In the process of developing the generic CE-diagram we found that the four company CE diagrams linked the occurrence of the pandemic to the problems identified, eventually boiling down to *loss of revenue* and *increases in cost*. The generic CE diagram linked the occurrence of a pandemic to

revenue and cost, with intermediate aspects, such as a consumer trust, market concentration, reliability in supply, and fixed assets structure. This made clear that we had identified “permanent” causal relationships that can be used for other purposes, such as continuous improvement of SCM. We used the results of the ESCF survey for another validation step of the generic CE diagram.

The generic diagram allowed to derive recommendations for actions in the discovery, recovery, and redesign phases. These recommendations were validated with the partner companies and where needed, reformulated. Furthermore, new recommendations were added. We concluded that each causal relationship could be subject of further research on SCM disruptions. With this in mind and taking into account the state-of-the-art in scientific knowledge on management of supply chain disruptions, we developed a research agenda.

With this we completed the project. We should note that the initial objective of developing tools for recovery and redesign of supply chains after a major disruption has not been met. We soon found out that this would require vast amounts of data, which were not readily available. As stated above, earlier research has led to tools that can be of use in the recovery phase, such as the so-called MAP-tool implemented at Philips Semiconductors (De Kok et al. (2005)). Initial tests with real-life cases at a high-tech company outside the consortium confirmed the capability of the MAP tool for running recovery scenarios in a few seconds. But as the CE diagram provided the holistic view we aimed for, we decided to focus on the development of the generic CE diagram. This can be seen as a qualitative tool for recovery and redesign.

### 1.7 RELEVANCE FOR BUSINESSES AND POLICYMAKERS

With our research we aimed to provide companies with insights, understanding and a hands-on tool to meet the challenges of mitigating the impact of the pandemic on their supply chains, and to support a fast recovery from the moment Covid-19 would be starting to get under control.

The CE-diagram (cf. Section 3), its explanation and its use is the major contribution of our research and can be seen as the tool we aimed for. The CE can be used in two ways.

Firstly, it helps to understand what went wrong and why. This implies tracking the causal relationships from pandemic occurrence (left) to revenue and costs (right).

Secondly, it helps to identify possible recovery strategies. This implies starting from revenue (right) and following the causal relationships upstream to find possible causes that can be mitigated or even neutralized by redesign. This is where we identify the need for visibility across the supply chain that allows us to manage the supply chain, such that goods are shipped to markets that demand for them and supplies can be sourced such that production rates can be maintained. Working upstream from costs we identify that we need ERP and APS systems, and business processes, that allow for running an S&OP process once a week instead of once a month. This is where we find the need for tight relationships between production and engineering to enable operational process resequencing to mitigate the impact of late delivery of supplies.

Thirdly, the CE diagram and its validation by the partner companies has led to a number of recommendations (cf. Section 4), that provide concrete further guidance for developing a contingency plan that enables effective action upon discovery of a major supply chain disruption, and during the recovery phase after that.

In line with what has been reported in public media, we found that the pandemic hit companies in many different ways. Some companies have increased revenues due to for instance hoarding and the need for using different modes of transport. Many have seen supplies halting due to lockdowns, productivity drops due to the 1.5m distancing, and personnel falling ill. This is why it is most important to have a means to be able to explain yourself the causal chains that apply to your supply chain, instead of being provided with answers that apply to all supply chains but yours.

The research agenda developed can provide a kickstart for

- the development of the tools needed to make the right trade-offs to create a resilient supply chain.
- The development of the tools to discover the weak links in your supply chain within days of the pandemic occurrence somewhere on the globe
- The development of the tools to recover from the pandemic in a sustainable and cost-effective manner, while adhering to the regulations changing over time.

## 2

## INTERVIEW AND SURVEY RESULTS

In this section, we focus on what happened (with respect to supply chains, suppliers, firm performances, demand and so on) to four firms during the crisis and present the results of the survey.

### 2.1 CASE STUDY ON 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 for their customers. Company A identified five markets marketing wise, namely industrial, consumer products, high-tech, automotive and health care. However, they have customers in all markets. Their business consists of 70% distributor of retail (B2B), 20% industrial and 10% e-commerce. However, due to the Corona crisis they expect the e-commerce business to increase. The management team of the operations of their customers are mainly located in The Netherlands, but the headquarters of these customers are spread all over the world. 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 are 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 has sub-contracts that 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 stick too much to the business model and not enough 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 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, 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 and increase the visibility in the chain. Furthermore, during the crisis, Company A did not buy own shares to be able to use this cash 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 additional customers for Company A. The financial stability of Company A during time 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, this plan accelerated decisions about actions that were already planned before Corona and it contributes to the preparation for a possibly second wave, indicating that they will be more robust for the future. Company A shared a lot of information with their 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 by 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 digital systems in place. This element shows that there is a high level of robustness. 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. The effects of working from home is an interesting topic for further research because it has never happened before at such a big scale and pace.

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 which is something that is not found in current literature, so it requires further research. 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 better out of the crisis than before.

## 2.2 CASE STUDY ON 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 the visibility in the supply chain and preventing 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 1.5, 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 this. The daily contact with suppliers concerning operational decisions is a form of collaboration that has a positive impact on the resilience of Company B. On the other hand, the limited interaction with suppliers and their tardiness in helping them is a form of lack of collaboration that has a negative impact on resilience. In addition, they prepare 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. This can result in more robustness in the future.

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 Corona, 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.

### 2.3 CASE STUDY ON 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 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 substituted by others, 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 is also because 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. Additionally, a Corona team was set up to deal with the main issues related to the crisis. 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). This may lead to a lower robustness level, which could lead to issues in the future. They indicate that the future is so uncertain that it is not valuable to put effort in creating a plan now. Still, 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 Automotive industry is vulnerable, so they should move their focus point 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. The fact that they have these scenarios indicates that they will be more robust for the future.

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 strong in information sharing 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 right now.

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 now 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.

#### 2.4 CASE STUDY ON 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 Semiconductor. These two markets are very stable markets, also during the Corona crisis. For the future, they expect that Healthcare will remain stable and that Semiconductor will be a stable growing market. However, there is still uncertainty about whether the Semiconductor industry will be as highly impacted as during the economic crisis.

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 these 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 has a good collaboration as result. 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 more 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 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 also 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 to ensure their robustness. 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 became 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. Because of their agile handling now, they will be robust for the future.

Another element contributing to the robustness of Company D, was that 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 have led to a reduction of new ideas, and the training of personnel became more difficult. Furthermore, meetings with customers could not be done physically anymore, which can be operationally challenging and can possibly lead to a decreased level of collaboration. As a consequence of the forced working from home, employees are more positive regarding the possibilities of working from home. Furthermore, 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. For germaphobe people, working in the office or in the factory could be a real challenge during the crisis. Besides this, it seemed that the hierarchical lines became more important during the Corona crisis and that the informal line and initiative taken by employees became less. In addition, people are less likely to report sick when 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. The effects of working from home is an interesting topic for further research because it has never happened before at such a big scale and pace.

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. 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.

## 2.5 SURVEY

Based on the interview questions and the findings of the interviews, a survey is created to learn more about how companies are impacted by COVID-19. Therefore, the survey is sent to other companies than the DASCOVIMI partners to gather more data; the members of the European Supply Chain Forum (ESCF). The objective of the survey is to back the findings of the qualitative interviews. According to Allen and Seaman (2007), surveys are consistently used to measure quality. The questions in the survey are mostly closed-form; binary questions, Likert scale questions, check-box questions and multiple-choice questions. Sometimes, scales are truncated to an even number of categories to eliminate the neutral option (Allen & Seaman, 2007). In this research, it is chosen to use a 4-point Likert scale to avoid people choosing neutral answers as well. For some questions, the option 'Other' is given, so the companies can provide own additions. There are also some open questions where companies can fill in numbers (%) to indicate changes in certain parameters, and sentences to explain plans for changes.

In the survey, first some general questions were asked to provide information about the type of company and the overall impact of COVID-19. Thereafter, questions regarding the operations of a 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.

In total, there were 10 companies that completed the survey, 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 6.

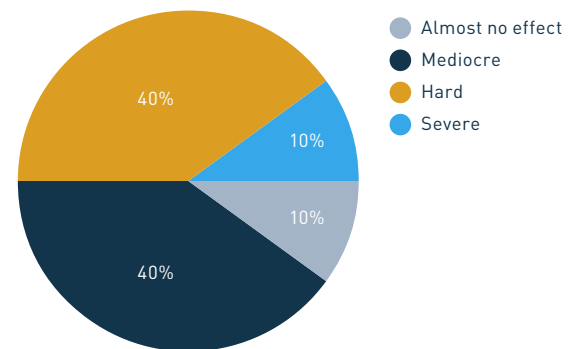


Figure 6. Survey question "How has your company been affected by COVID-19?"

Overall, the results of the survey support the results of the interviews with the DASCOVIMI members. Therefore, the CE-diagram that is created provides a complete overview of what happened during the Corona Crisis, based on the interviews and survey. The results of the survey are worked out and can be found in Appendix B.



3

# CAUSE-EFFECT DIAGRAM

Based on the four individual Cause-effect (CE) diagrams presented in Appendix A, one generic cause-effect diagram is created. The generic cause-effect diagram is shown in Figure 7 in this section. This CE diagram provides a generic diagnosis of problems and their causes that companies can experience during pandemics and other major disruptions. The boxes of the generic CE diagram are individually described in Appendix C. Additionally, there is explained how a qualitative and/or quantitative analysis can be performed for each box and where the necessary information can be retrieved. A summary of all this information is provided in Table 1.

## 3.1 GENERIC CAUSE-EFFECT DIAGRAM

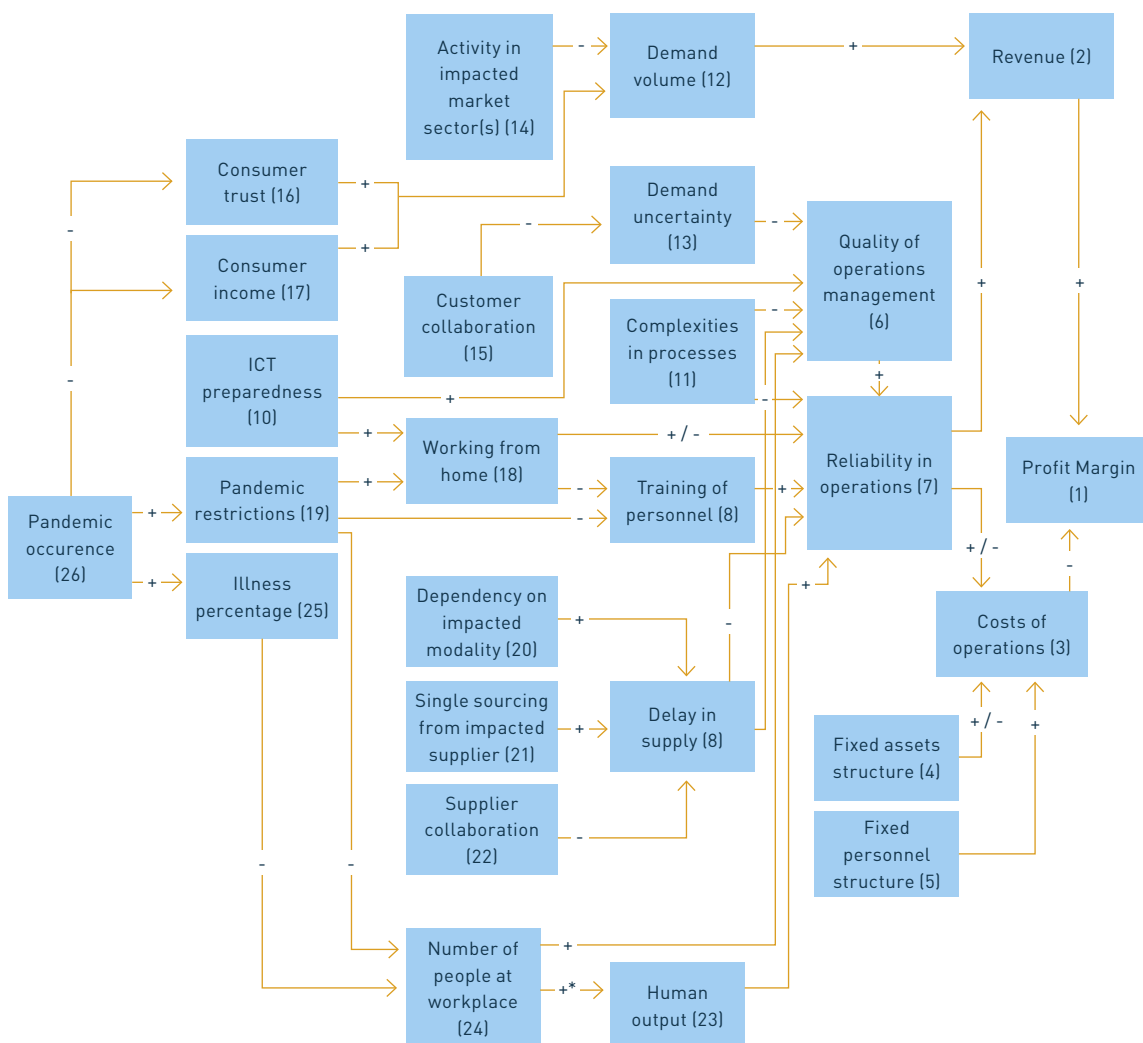


Figure 7. Generic CE-diagram with relations

## 3.2 PROBLEMS IN THE PANDEMIC DISRUPTION

No	Box name	Content of the box	Measure	Where/how to find information?
1	Profit margin	<ul style="list-style-type: none"> <li>Gross profit margin</li> <li>Operating profit margin</li> <li>Net profit margin</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Income statement or profit &amp; loss statement</li> </ul>
2	Revenue	<ul style="list-style-type: none"> <li>Revenue</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Income statement or profit &amp; loss statement</li> </ul>
3	Cost of operations	<ul style="list-style-type: none"> <li>All types of costs a company can face</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Income statement or profit &amp; loss statement</li> </ul>
4	Fixed assets structure	<ul style="list-style-type: none"> <li>Fixed assets or non-current assets</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>Balance sheet or statement of financial position</li> <li>Interview questions</li> <li>Survey</li> </ul>
5	Fixed personnel structure	<ul style="list-style-type: none"> <li>Percentage of employment contracts that cannot be terminated in the short term</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Human resource department</li> </ul>
6	Quality of operations management	<ul style="list-style-type: none"> <li>Planning and management of operations</li> <li>Demand and supply match</li> <li>Planning of employees</li> <li>Material planning</li> <li>Flexibility in times of disruption</li> <li>Contingency plan for emergency</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Demand levels</li> <li>Supply levels</li> <li>Previous forecasts</li> <li>Interview questions</li> <li>Survey</li> </ul>
7	Reliability in operations	<ul style="list-style-type: none"> <li>Actual vs planned supply levels</li> <li>Actual vs planned demand levels</li> <li>Actual vs planned inventory levels</li> <li>Output operations</li> <li>Compliance to plans that are made in operations management</li> <li>On time delivery (Lead time)</li> <li>Re-scheduling of operations</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Forecast supply</li> <li>Forecast demand</li> <li>Actual supply levels</li> <li>Actual demand levels</li> <li>Inventory levels</li> <li>Production data</li> </ul>
8	Training of personnel	<ul style="list-style-type: none"> <li>Ability and ease with which new and current employees can be trained</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>Interview questions</li> <li>Survey</li> </ul>
9	Delay in supply	<ul style="list-style-type: none"> <li>On time delivery of supply</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>On time in full (OTIF) data</li> <li>Conversations with suppliers</li> </ul>
10	ICT preparedness	<ul style="list-style-type: none"> <li>ICT systems in place (e.g. Teams or VPN servers)</li> <li>Planning systems in place (e.g. ERP or SAP)</li> <li>Data (sharing) capabilities</li> <li>Performance dashboards</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>Interview questions</li> <li>Survey</li> <li>ICT department</li> </ul>
11	Complexity in processes	<ul style="list-style-type: none"> <li>Internal and external processes</li> <li>Number of steps in the processes</li> <li>Number of resources and materials needed in the process</li> <li>Number of supply chain partners involved in the process</li> <li>Number and complexity of different products</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>BOP</li> <li>BOM</li> <li>Interview questions</li> <li>Survey</li> </ul>
12	Demand volume	<ul style="list-style-type: none"> <li>Demand levels</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Demand levels</li> <li>Order data</li> </ul>
13	Demand uncertainty	<ul style="list-style-type: none"> <li>Uncertainty about demand</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>Interview question</li> <li>Survey</li> </ul>

No	Box name	Content of the box	Measure	Where/how to find information?
14	Activity in impacted market sector(s)	<ul style="list-style-type: none"> <li>Number of industries/sectors in which company is active</li> <li>Amount of impacted industries</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Annual report</li> <li>Interview questions</li> <li>Survey</li> <li>Sources that publish statistical information about a country, like Centraal Bureau voor de Statistiek (CBS)</li> <li>Order data</li> </ul>
15	Customer collaboration	<ul style="list-style-type: none"> <li>Information shared by company with customers</li> <li>Information shared by customers with company</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>Interview questions</li> <li>Survey</li> </ul>
16	Consumer trust	<ul style="list-style-type: none"> <li>Consumer's trust in economy</li> <li>Consumer's willingness to spend money</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Interview questions</li> <li>Survey</li> <li>Sources that publish statistical information about a country, like CBS</li> </ul>
17	Consumer income	<ul style="list-style-type: none"> <li>Consumer's ability to spend money</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Sources that publish statistical information about a country, like CBS</li> </ul>
18	Working from home	<ul style="list-style-type: none"> <li>Ability to work from home</li> <li>Effects of working from home</li> <li>Number or percentage of workforce that is/ has been working from home</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Interview questions</li> <li>Survey</li> <li>HR reports/database</li> </ul>
19	Pandemic restrictions	<ul style="list-style-type: none"> <li>Containment measures taken by government</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>Sources of a country's government</li> <li>News sources</li> </ul>
20	Dependency on impacted modality	<ul style="list-style-type: none"> <li>Dependency on certain modality: road, air, sea, rail, pipeline</li> <li>Impact on certain modality</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>Annual report</li> <li>Interview questions</li> <li>Survey</li> </ul>
21	Single sourcing from impacted supplier	<ul style="list-style-type: none"> <li>Dependency on supplier(s)</li> <li>Number of suppliers per material/product/component</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Interview questions</li> <li>Survey</li> <li>Supply data</li> </ul>
22	Supplier collaboration	<ul style="list-style-type: none"> <li>Information shared by company with suppliers</li> <li>Information shared by suppliers with company</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative</li> </ul>	<ul style="list-style-type: none"> <li>Interview questions</li> <li>Survey</li> </ul>
23	Human output	<ul style="list-style-type: none"> <li>Total amount of acceptable output during a period of time that can be achieved by the employees that perform a certain operation</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Department in which the operations are performed</li> </ul>
24	Number of people at workplace	<ul style="list-style-type: none"> <li>The number of employees that fit and are present at a workstation/workplace</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Operations manager</li> <li>Manager of production division</li> </ul>
25	Illness percentage	<ul style="list-style-type: none"> <li>Proportion of employees of a company that are reported sick and that are unable to perform their work for a certain period of time</li> </ul>	<ul style="list-style-type: none"> <li>Quantitative</li> </ul>	<ul style="list-style-type: none"> <li>Human resource department</li> </ul>
26	Pandemic occurrence	<ul style="list-style-type: none"> <li>Root cause of all issues</li> </ul>	-	-

Table 1. Survey question "How has your company been affected by COVID-19?"

### 3.3 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 7. It should be noted that the relations between the elements are general relations that are based mainly on the findings of this research or 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 7 with a \*.

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 Appendix C (see Figure 31 and Figure 32), 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 Appendix C (Figure 33 and Figure 34), 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 31 and Figure 32 in Appendix C), 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.

#### **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 very 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/negative 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. However, this is not always the case. An increase in demand can have different consequences due to differences in a company's asset strategy. In a situation where a firm faces an increase in demand (imagine a firm manufacturing the COVID vaccine), cost of operations would drop for a firm with higher fixed assets. This is the consequence of a firm's operating leverage. High fixed costs increase the leverage, whereas low fixed costs will reduce it. A firm with higher leverage will see a higher profit when demand increases as compared to a firm with a lower leverage. This indicates a negative relation. Therefore, the relation between Fixed assets structure and Cost of operations can either be positive or negative.

The other relations in the CE diagram are rather obvious and do not need further explanation. These relations can be found in Appendix D.

## 4

## 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 also Figure 4. In the discovery phase, it is most 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 the next disruption. The recommendations from our research are structured into these three phases. Within the phases the recommendations are not structured in an arbitrary way. If they are followed in the order stated in each phase, they serve as a checklist during and after times of disruption.

### 4.1 DISCOVERY

**Critically analyse and monitor internal processes and external information.**

In order to be able to detect a disruption as soon as possible, it is important to frequently monitor public and private information, e.g. weather forecasts, political instability, signals on business instability from stock markets, in relation to the customer and supplier base. This information must be carefully interpreted. From the survey, we found that companies are monitoring their financial information more frequently during the Corona crisis. Additionally, monitoring inventory levels and KPIs (more frequently) is effective for early discovery of issues related to a disruption. Quick recognition of a major Supply Chain disruption is vital for a company's competitive position. Only then can recovery to the original state of the supply chain can begin (Macdonald & Corsi, 2013). Be sure you are not the only company in your markets

### 4.2 RECOVERY

**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 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 provided by 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.

**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, it became clear that there was a lack of clarity 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 had 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.

**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 decision 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.

**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 functions (e.g. production, R&D, supply chain) in a company work closely together so they can share their knowledge about the operations and demand. However, it should be noted that not all (parts of) processes can be flexible. In such a case, a recommendation can be to have (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 the interviews it emerged that a particularly challenging factor in determining strategies to react to the Corona disruption was the lack of transparency from suppliers and/or customers, increasing the uncertainty in the company's 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.

### 4.3 REDESIGN

#### **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 create 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.

#### **Evaluate 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 continue 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 some 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 clear documentation and an explicit representation of the supply chain network structure and of the processes related to operations management. This must be complemented with information systems tailored to support operational processes (e.g., WFM, SAP, ERP), that allow to standardize and simplify process management, thus enhancing efficiency and effectivity, as well as to identify in advance potential exceptions/issues and work out appropriate solutions. These systems also allow 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 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.

#### **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 regarding the recovery phase related to 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 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.

**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 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 (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 number 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 can reveal possible issues during disruptions.

**Evaluate sourcing strategy, taking into account the global impact of a pandemic.**

Different than the financial crisis and the tsunami's in Asia, supply chains have been affected by global lockdowns by the Corona pandemic. This made clear that often proposed dual sourcing strategies may adversely affect companies. This can be explained by the fact that with suppliers at different continents or political unions, it is more likely that at least one of the suppliers is affected by the pandemic. If suppliers and company are located in the same region, they are affected in the same way by the pandemic, whereby a supplier in lockdown implies that the company is in lockdown as well. Such correlations between disruptions at different links in the supply chain are seldom taken into account when considering sourcing strategies. Clearly, this must be taken into account when considering possible future major supply chain disruptions.



## 5

## CONCLUSIONS

**DASCOVIMI is an acronym for ‘Disruption Analysis of the SC due to Corona Virus, based on actual information, with focus on Manufacturing industry’. In this explorative research project, we were able to obtain high-level insights into how the COVID-19 pandemic has impacted the manufacturing industry, as well as the logistics sector. Four firms were studied in detail, with multiple interviews and workshops with different stakeholders within the firms. Furthermore, we conducted large scale surveys with ESCF members to see the impact across other industries as well.**

The COVID-19 pandemic has adversely affected pretty much every economy in the world. Not only has it changed the way we work and travel, it also heavily disrupted international supply chains and networks. Multiple modalities of transport were affected. Early in 2020, almost 95% of containers leaving Chinese ports were empty. Belly freight (air transport) also saw a massive reduction for several months. This severely impacted the parts supply for the diverse interconnected manufacturing sector. The impact on a firm’s operations is dependent on the impact on markets in which it is active. Furthermore, local government rules and decisions also led to many disruptions. For example, several countries in the EU closed their borders on several occasions. The lack of a centralized European set of rules was seen as a major cause of this. Work shifted from the office to home, bringing several challenges for families as well as firms. Immediate ICT support was necessary, and people had to adapt to the new normal of working online. Even though it was not possible to obtain a real “office atmosphere”, and several employees pointed out they were missing the possibility of having informal chats to discuss daily matters rather than having to schedule telco, the ICT made anyway available suitable alternatives for employees (e.g., teams meeting) to keep regular contacts and to make feel people still part of the company.

In this project, we structured all this information and the insights from the interviews, surveys and workshops into a generic Cause-Effect (CE) diagram. This CE diagram helps to provide a generic process for diagnosing the problems that can arise due to pandemics and other big disruptions. The CE diagram can be used to identify the repertoire of actions to break the causal chain between pandemic occurrence (major disruption) and the impact on a

company’s 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. The use of this diagram can help to make a list of possible actions or interventions to mitigate the impact of such disruptions. For 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 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 overtime, more hires, 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.

Of the 4 firms we studied in detail, we observed that 3 of them were not severely hit by the pandemic. A few saw dips in demand and revenue but were able to return to pre-pandemic levels by the summer. In particular we noticed that working from home was not a bottleneck for continuing business. Most firms already had suitable ICT infrastructure in place and were able to cope with the increased demand of internet services. 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. Several of the companies we interviewed and surveyed organized high-level executive meetings to create a plan for how they will work during the pandemic

and what the exact responsibilities are. It was necessary for firms to be creative, flexible and innovative in managing their organization. Flexibility and the ability to quickly adapt to disruption changes had been crucial for effective cost management. Additionally, data transparency and visibility were very important (and it still remains a big challenge). A firm needs to be aware of not only its immediate supply chain partners, but also those in the 2<sup>nd</sup> and 3<sup>rd</sup> tier. Such network level visualization can significantly improve planning and survival of a firm.

We also provide a repertoire of recommendations for discovery, recovery and redesign a firm should undertake during such disruptions. A particular company can determine what measures are appropriate in its situation by using the CE diagram to find the relevant causal chains and relations, and to run these backwards. In that way an effective pandemic management expert system can be created.





## FURTHER RESEARCH DIRECTIONS

In conducting our study, we identified numerous avenues for future research. These ideas are based on our observations from the CE diagram, the ESCF survey, and our numerous in-person interviews with industry partners. We broadly split them into 3 parts: General extensions, Data driven process support, and Networks & finance.

### GENERAL EXTENSIONS:

The following ideas can be studied either with a strong data-driven approach or using a mathematical modelling approach.

**Sourcing and buffer strategies:** In a geographically diverse economy, both the suppliers and the focal firm have correlated risks. This introduces the question of supplier selection – is it better to have suppliers closer or farther away? In a pandemic or general worldwide disruption, a firm would want to change its objectives from minimizing costs to ensuring that they are less affected than the competitors. This brings a unique outlook to determining safety stocks and buffers.

**Recovery planning and execution:** As we have seen from the current pandemic, demand changes drastically during disruptions. In these scenarios, it is likely that the entire product range need not be produced. Output for a fixed selection of products can be maximized over the recovery horizon. The problem can focus on the optimal product mix that can minimize resource use and maximize performance and output.

Furthermore, we found that current operational planning support systems, like MRP I, are based on propagating gross requirements upstream, without any check on upstream material availability. This may work under normal business conditions, but it clearly does not work when supply chains are out-of-balance, whereby material availability must be propagated downstream to markets that want more than is available. Developing allocation mechanisms and operational problem-solving support for material-constrained supply chains with immediate response to allow for interactive planning, is paramount to meet the SCM challenges during recovery of a pandemic or other major disruption.

**Extending the CE diagram:** The current version of the CE-diagram is quite general in nature. It

is possible to zoom in on specific cause-effect chains in order to create measurable concepts. These concepts are the basis for dashboards to aid in efficient supply chain management during disruptions. The qualitative approach used during the DASCOVIMI project can be used, but a more thorough scientific approach ensures that concepts and tools have a stronger foundation.

### DATA-DRIVEN PROCESS SUPPORT

**Supply Chain visualization:** Most of the companies involved in the project already have an ICT infrastructure able to monitor the most relevant process KPIs. However, KPIs alone are often not enough to support the management of organization processes, especially during a crisis. For example, indicators can reveal whether there is a performance problem in one or more processes, but not the root causes of such problems. Furthermore, indicators do not provide a holistic overview on how the process is actually performed in its various phases. Without such overview, process actors tend to focus on their own functions, with the result that valuable knowledge about the process is scattered in different level of granularities among different actors. This poses important challenges when processes have to be changed or reorganized quickly, to face crises or disruptions. It is worth noting that similar issues can be found also at the level of the supply chain. Indeed, usually different partners in a SC are only aware of their own function/products within the chain; however, a general snapshot of the overall chain, with its related processes, describing both the single partners' roles and their interconnection (and dependencies) is missing. It has been often discussed in literature that a proper visualization of the overall SC and its related processes has the potential to bring significant improvements both to the efficiency of the SC operations and to the reliability of the collaboration among the SC partners. This last point proved to be especially

critical during the Corona crisis. Indeed, an issue frequently highlighted from the interviewed companies was the lack of transparency from their partners in the SC, which slowed down the development of reaction strategies.

**Supply chain mining:** Despite the above-mentioned benefits of having a proper visualization of the SC processes, today mostly theoretical, high-level models are available, which do not allow to represent the reality of the specific chain at hand. As future research direction, we aim at fulfilling this gap. To achieve this goal, we intend to apply principles of *process mining* discipline. Process mining is able to provide an x-ray on how organization processes are actually performed and enables data-driven analysis aimed at, e.g., determining anomalous executions, localize bottlenecks, investigating process actors' collaborations and so on. In particular, we plan to extend process mining towards the development of a supply chain mining approach, which implies developing process mining techniques for inter-organizations processes. Inter-organizations process mining brings a number of additional challenges with respect to classic intra-organization approaches.

**Information sharing:** Indeed, inter-organizational processes involve independent parties, which means, for example, having to interface heterogeneous information systems. Furthermore, there is the need of investigating appropriate process representation formalisms to represent the SC processes, e.g., to represent different level of abstractions (single organization/ entire chain). Finally, one or more parties might actually be reluctant in sharing detailed process data with others. We intend to address these challenges by elaborating upon previous research on inter-organizations governance methodologies and multi-party data exchange solutions (e.g., federated databases, and secure multi party's computation disciplines). At the same time, we plan to develop suitable formalisms for inter-organization processes formalization.

## SUPPLIER COLLABORATION, LIQUIDITY AND ASSET MANAGEMENT

To understand the effective implementation of our recommendations, we envisage that there is a need for strong data driven and mathematical modelling-based research around ideas such as supplier collaboration, liquidity management, and asset structure. We briefly summarize these ideas into four categories.

**Supplier Collaboration:** One of the important aspects from the interviews regarding the recovery time of firm during the crisis is the assistance provided to the supplier by the firm. This suggest that a strong collaboration with suppliers can help firms to mitigate the risk better. A possible research hypothesis regarding this idea could be - *firms that assist suppliers during the disruption discovery phase is likely to recover faster*. A sub-hypothesis could also be that supplier assistance is likely to reduce the lead time.

**Better Liquidity Management:** From the discussion with companies and our research suggest that firm's level of liquidity can help them absorb cash shock. So, it would be great to understand what elements of liquidity management are crucial in absorbing shocks. As an example, a possible hypothesis could be - *higher levels of liquidity and working capital is likely to reduce the shock response time*.

**Enhanced Flexibility and Monitoring:** Our results from ESCF survey strongly suggest that flexibility and frequent monitoring of operations variable can help firms to react quickly to the during the crisis. So, it would be good idea to evaluate this hypothesis - *increase in the level of operations flexibility and frequency of monitoring (S&P cycle, financial/ operations parameters) are likely to reduce financial loss incurred due to crisis*.

**Balancing Asset and Personnel Light Structure:** A balance between asset-light and personnel light strategy can help a firm to design stronger contingency plans. This may lead to quicker recovery and better redesign after a disruption. In this case, we may consider variables like - employee performance, supplier/employee trust, operating leverage, flexible contracts, and so on *to develop a mathematical model to understand the optimal levels of assets and number of employees with flexible contracts*.

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## A

## CAUSE-EFFECT DIAGRAMS OF EACH FIRM

### CAUSE-EFFECT DIAGRAM COMPANY A

The cause-effect diagram of Company A is presented in Figure 8. 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. 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 the Company A warehouses. 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. Additionally, because of the 1.5 metres restriction, many employees had to work from home causing no physical meetings with customers. Besides that, the 1.5 metres restriction caused that the Company A 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 site. 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.

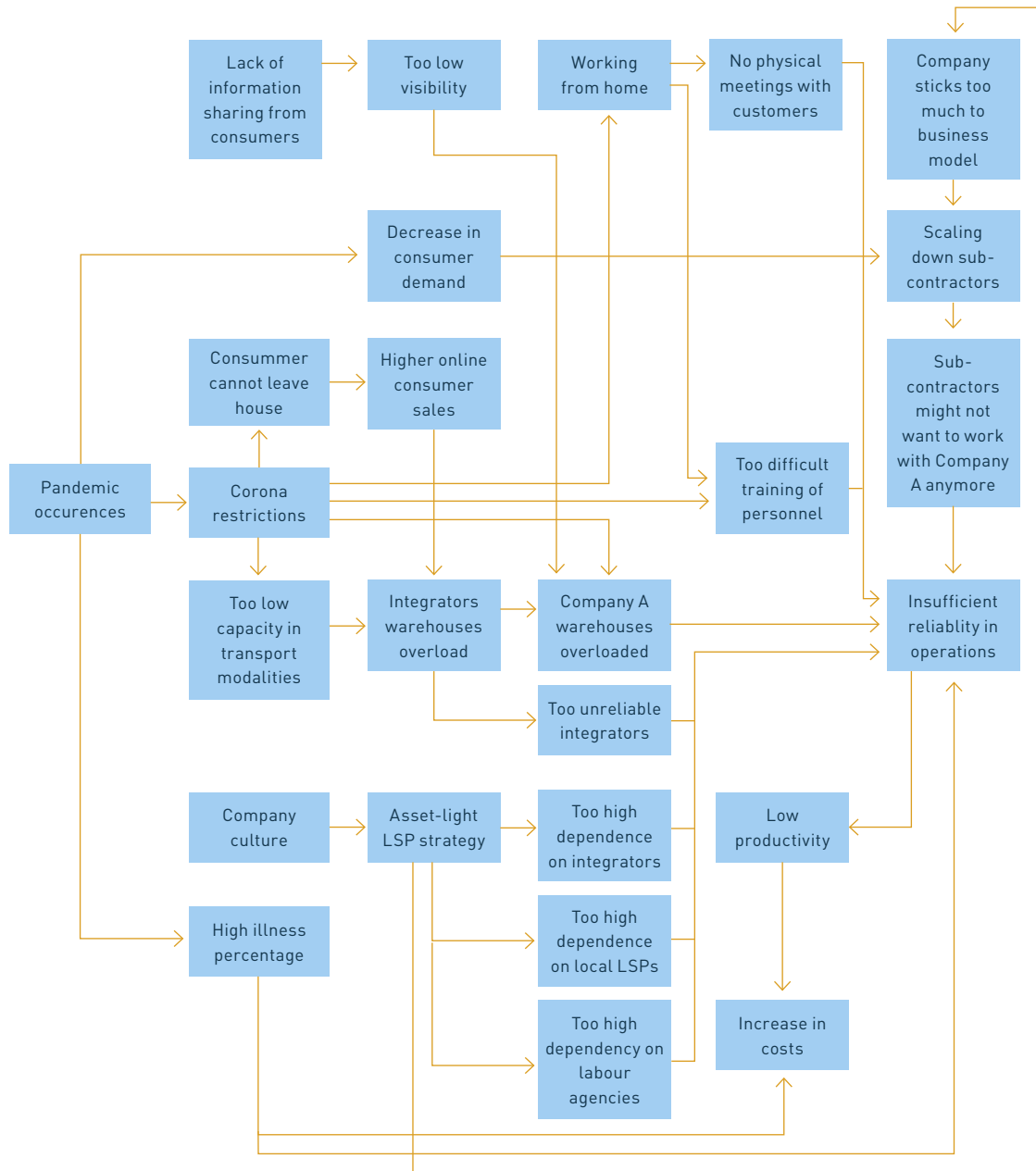


Figure 8. Cause-effect diagram Company A

**CAUSE-EFFECT DIAGRAM COMPANY B**

The cause-effect diagram of Company B is presented in Figure 9. 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. The Semiconductor 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 Semiconductor in the upcoming months/ years. In turn, this possible decrease of demand could cause possible uncertainty about demand in the future.

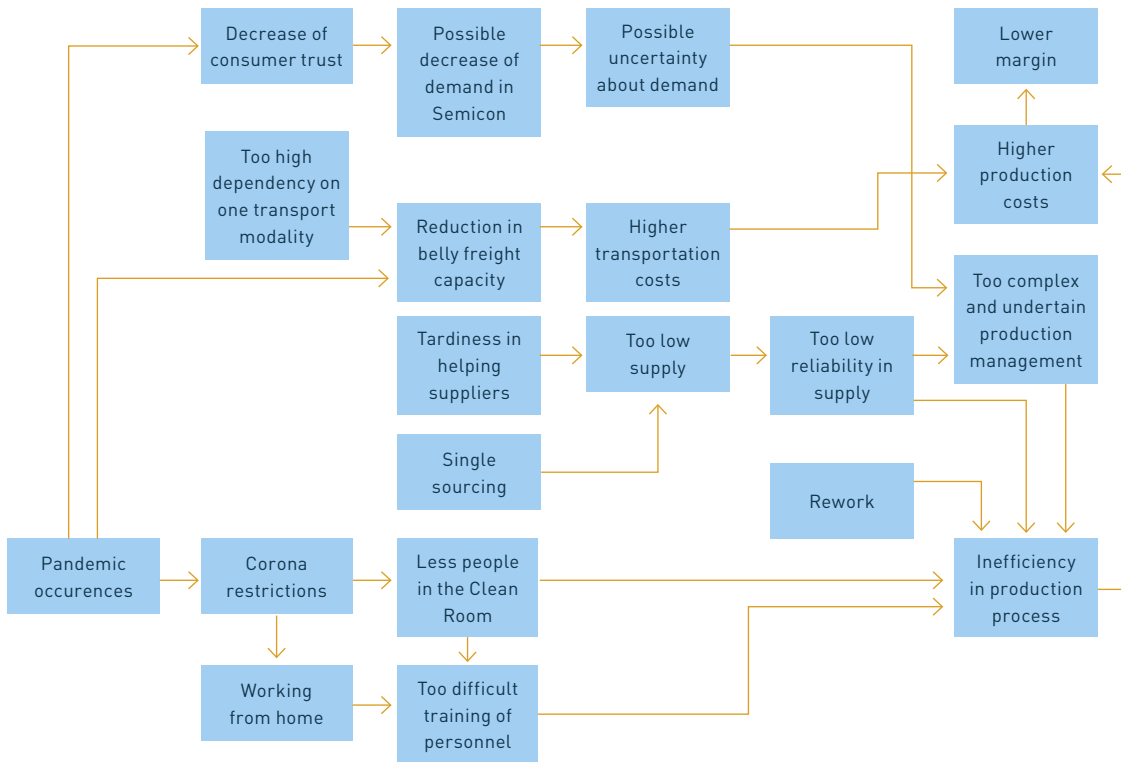


Figure 9. Cause-effect diagram Company B

### CAUSE-EFFECT DIAGRAM COMPANY C & COMPANY CA

The cause-effect diagram of Company C and Company Ca is presented in Figure 10 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 site. 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, so 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.

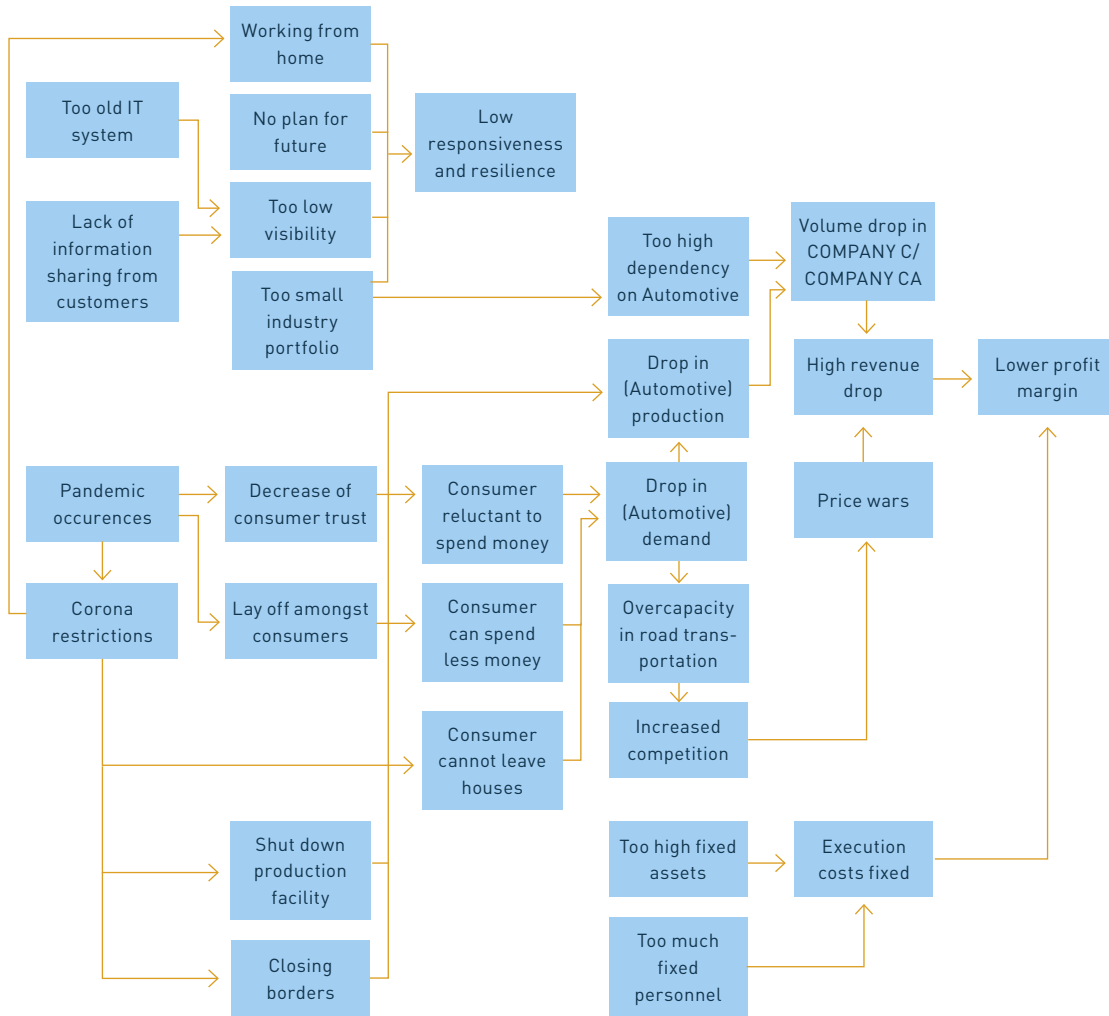


Figure 10. Cause-effect diagram Company C & Company Ca

**CAUSE-EFFECT DIAGRAM COMPANY D**

The cause-effect diagram of Company D is presented in Figure 11. 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 Semiconductor 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 Semiconductor, which implies that they are dependent on both markets. When one of these markets will be hit, Company D will have a big problem.

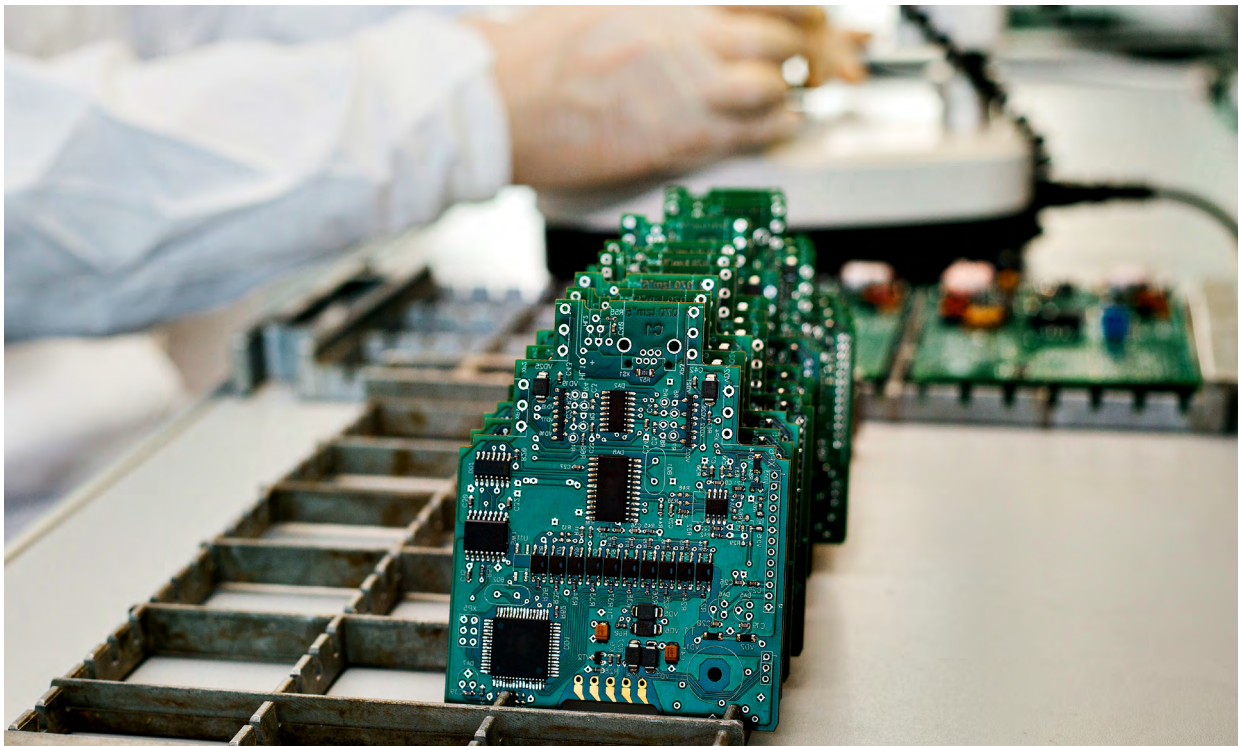
The occurrence of the Corona pandemic caused restrictions that are created by the government. An example of such restriction is the 1.5 metres



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 Son. 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.



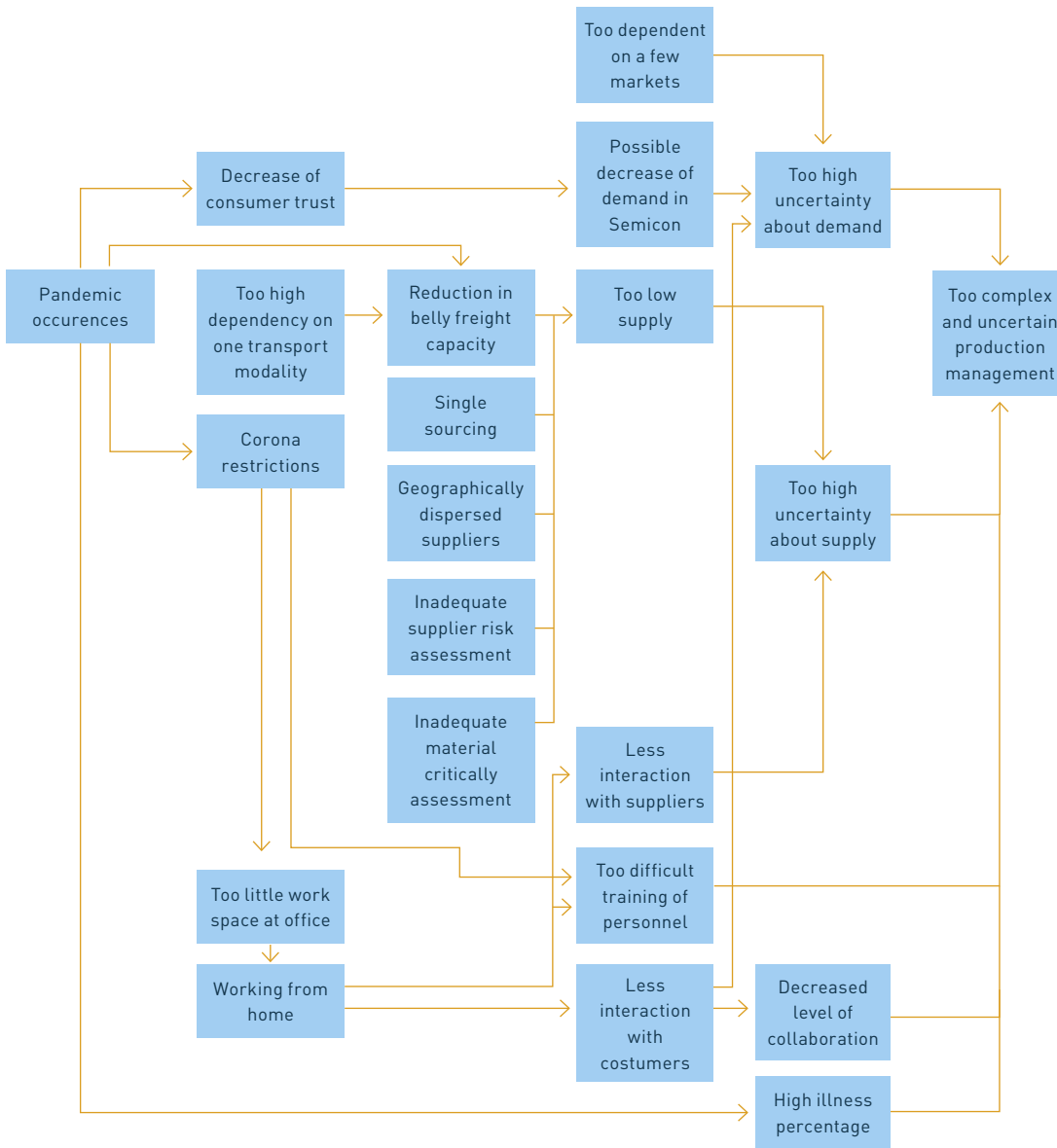


Figure 11. Cause-effect diagram Company D

**B**

# RESULTS SURVEY

This appendix contains the results from the survey that is send out to the ESCF members.

## DEMAND LEVELS

The demand levels of 7 out of the 10 companies have decreased, see Figure 12 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.

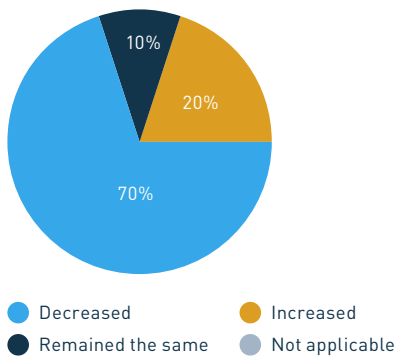


Figure 12. Survey question "What happened to your demand levels?"

## PRODUCTION LEVELS

Figure 13 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.

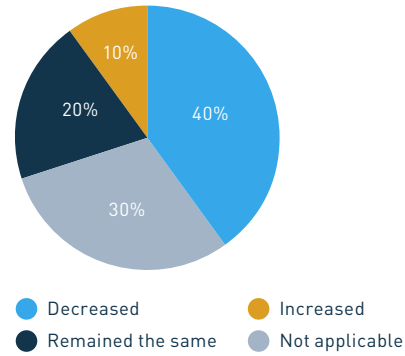


Figure 13. Survey question "What happened to your production levels?"

## SUPPLY LEVELS

In Figure 14 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.

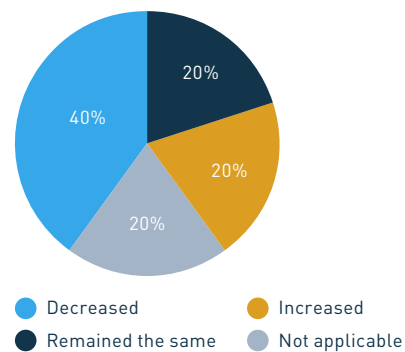


Figure 14. Survey question "What happened to your supply levels?"

**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 15 (Left). The main reasons are the Corona restrictions and measures, lower inbound levels, and lower outbound levels. We asked the companies 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 15 (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.

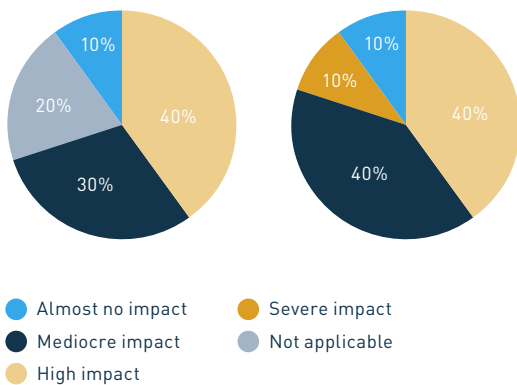


Figure 15. Survey questions “What is the impact on the operations in your warehouse(s) due to Corona?” (Left) and “What is the impact on your transportation?” (Right)

**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 16 below, it can be seen that 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 in 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.

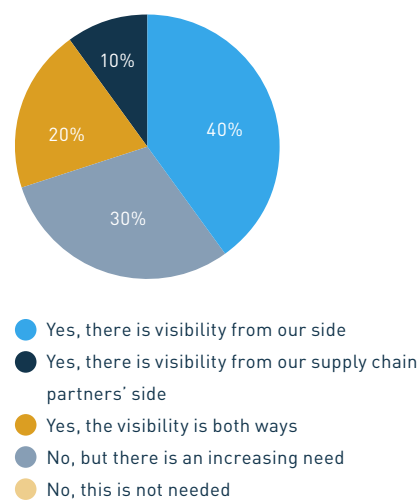


Figure 16. Survey question “Is there visibility in your supply chain?”

**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 was only one company 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 17. 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.

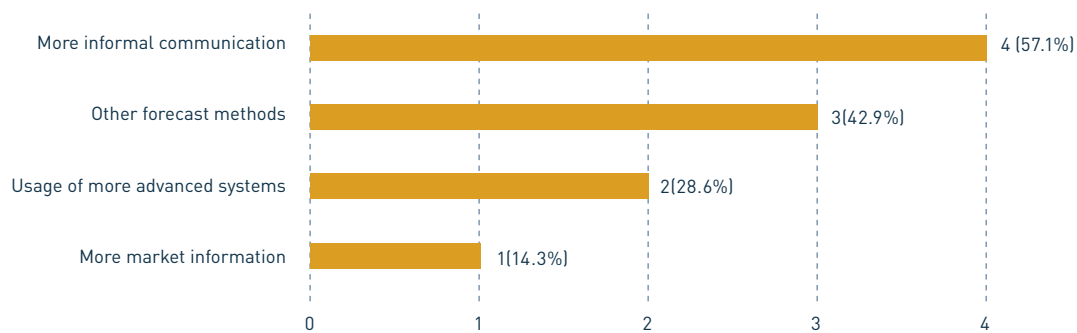


Figure 17. Survey question "How are you going to change the forecast model?"

**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 18. 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.

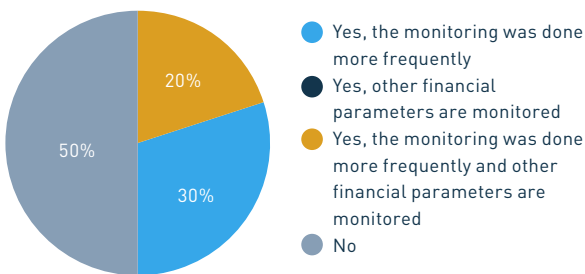


Figure 18. Survey question "Does the monitoring of these financial parameters change due to the Corona crisis?"

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 19, 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.

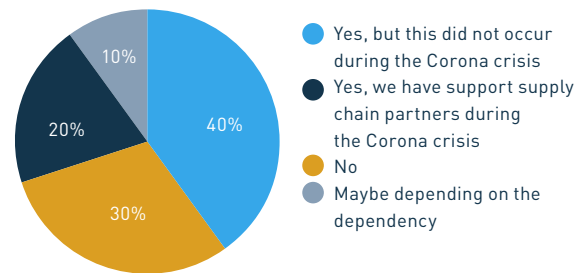


Figure 19. Survey question "Will you financially support a partner in your supply chain when they are affected by a disruption?"

**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.

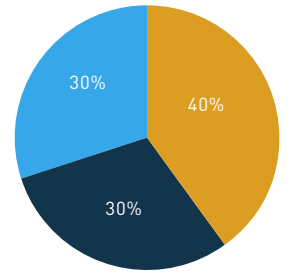


### WORKING FROM HOME

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 20. 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.



- Yes, there is always an increase
- Yes, there is always a decrease
- No

Figure 20. Survey question "Has there been a change in the illness percentage due to the Corona crisis?"

### 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.





## EXPLANATIONS AND DATA ANALYSES CE DIAGRAM

This Appendix contains an explanation of each box in the CE diagram, and data analysis is performed if possible. 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 companies in the DASCovIMI consortium, an example of the data analysis during the Corona crisis is provided.

### 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).

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

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

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

**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.

**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).

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 21 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.

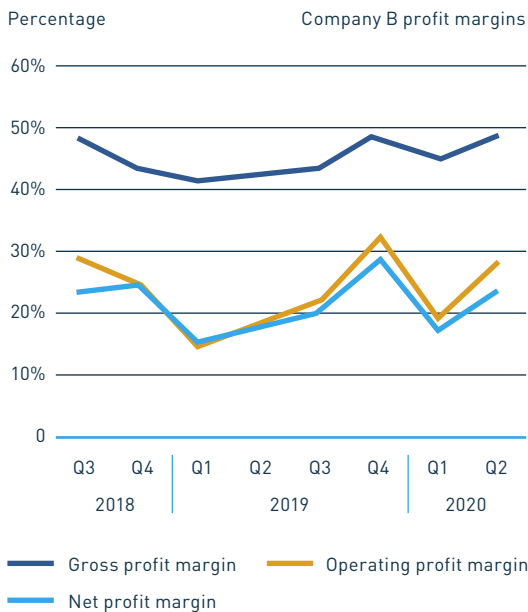


Figure 21. Company B Profit margins over time

The same analysis is also done for Company A. Based on Company A's income statement, the profit margins are calculated. In Figure 22, 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.

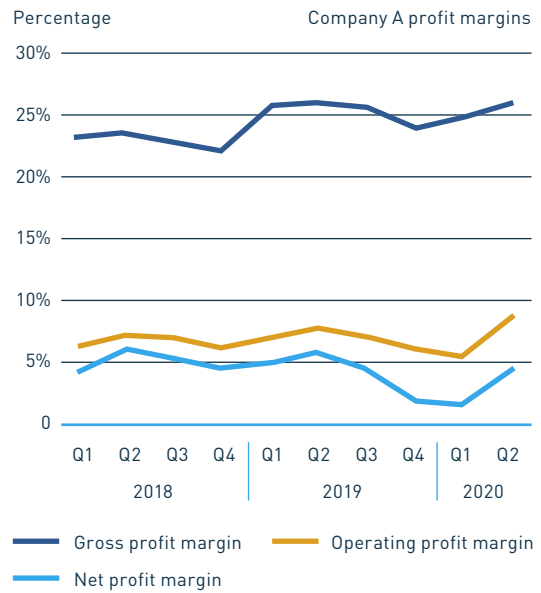


Figure 22. Company A Profit margins over time

**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 23), 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 was 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.

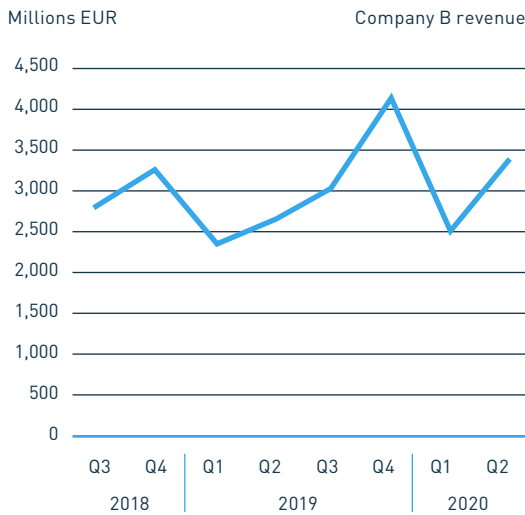


Figure 23. Company B Revenue over time

Figure 24 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.

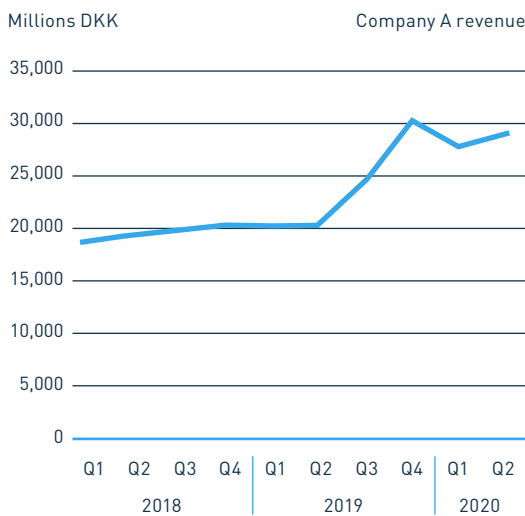


Figure 24. Company A Revenue over time

**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 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 25, 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 26, 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.

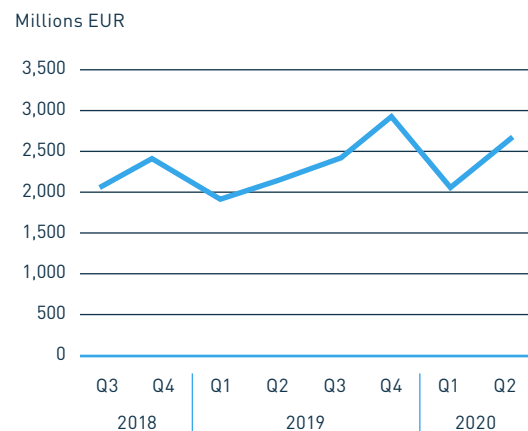


Figure 25. Company B Total costs of operations over time

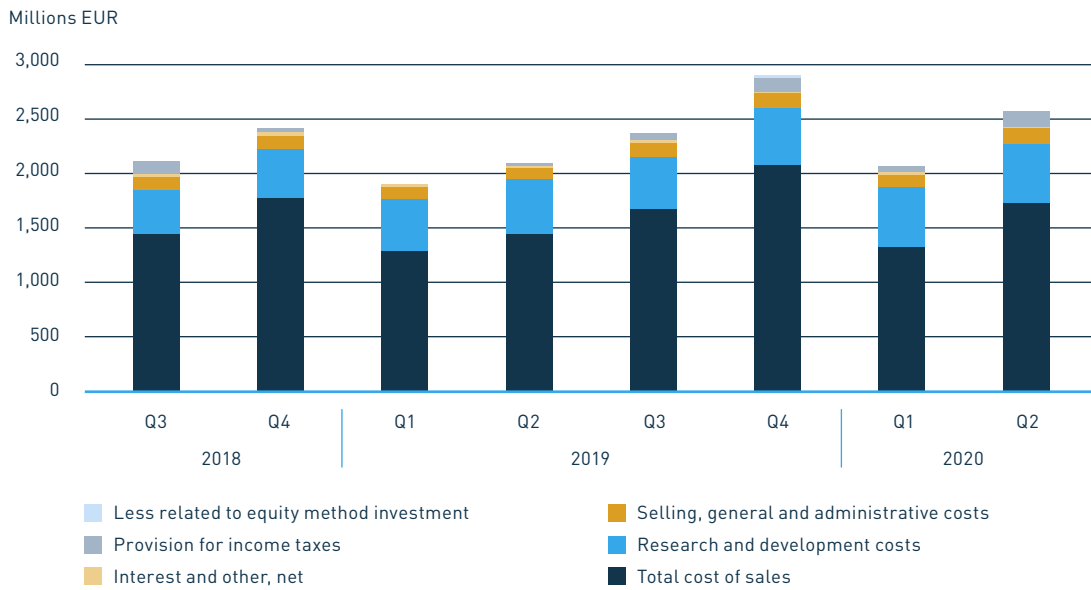


Figure 26. Company B Composition of total costs of operations over time

The total costs of operations are also analysed for Company A, based on its income statement. In Figure 27, 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 28, 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 another name for costs of sales. 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. Therefore, it can be deduced that Company A did not encounter any major changes in its costs because of the Corona Pandemic.

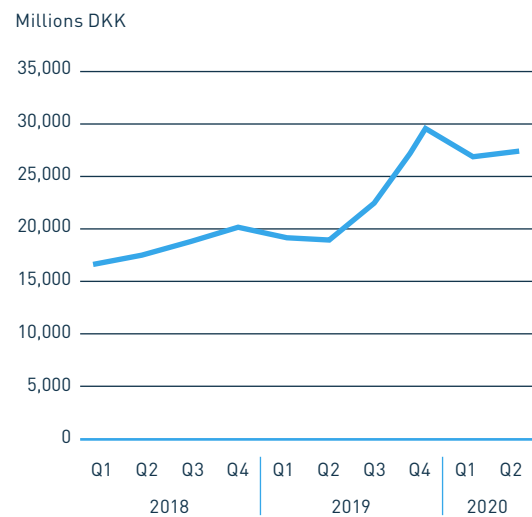


Figure 27. Company A Total costs of operations over time

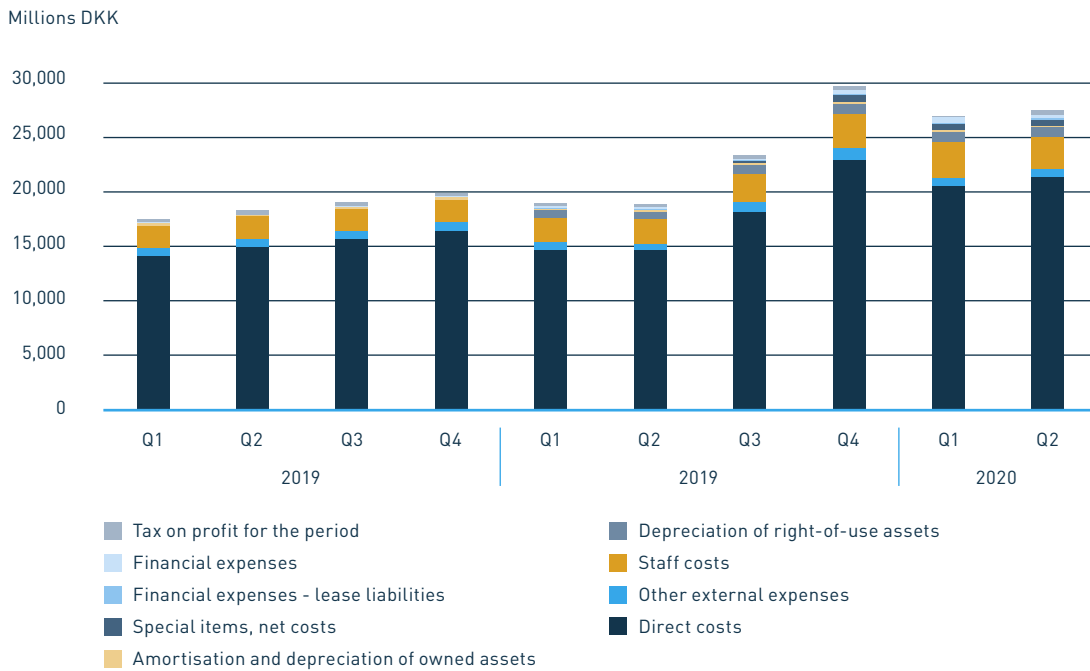


Figure 28. Company A Composition of total costs of operations over time

### 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 29, 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 30. It can be derived that the relatively small 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.

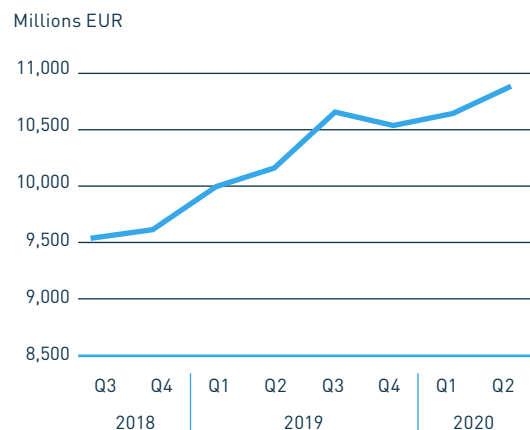


Figure 29. Company B Total fixed assets over time



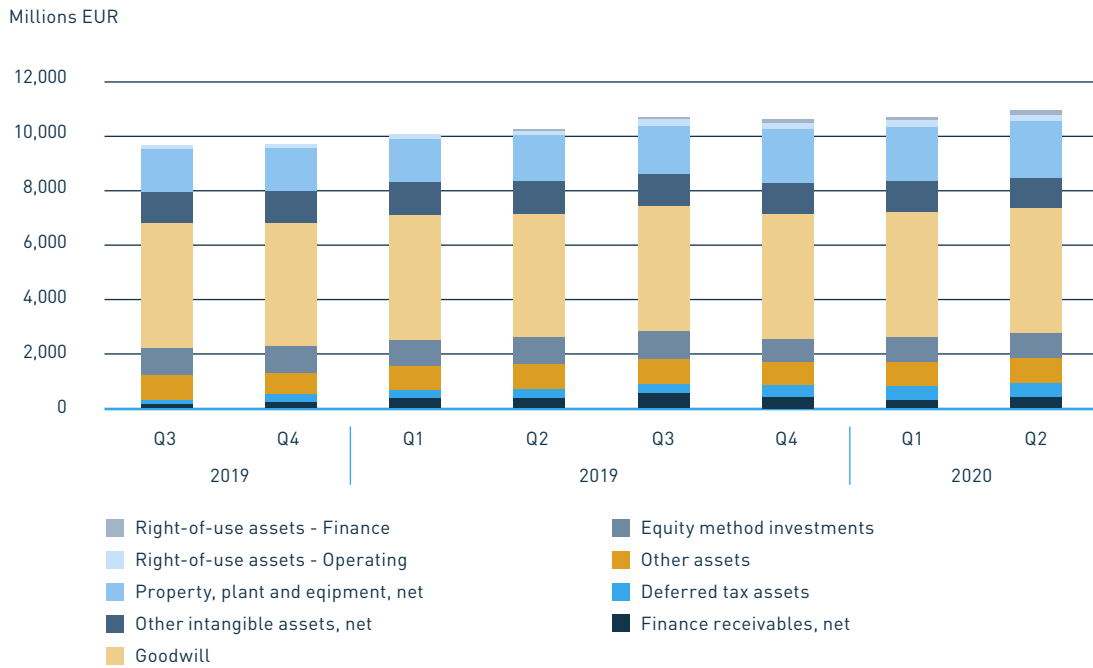


Figure 30. Company B Composition of total fixed assets over time

**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 changed 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. 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.

### 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 behaviour 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 31 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.

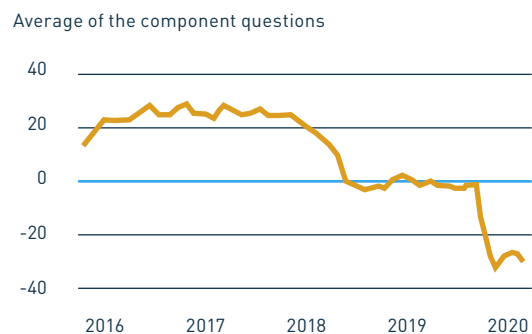


Figure 31. Consumer trust in the Netherlands (CBS, 2020c)

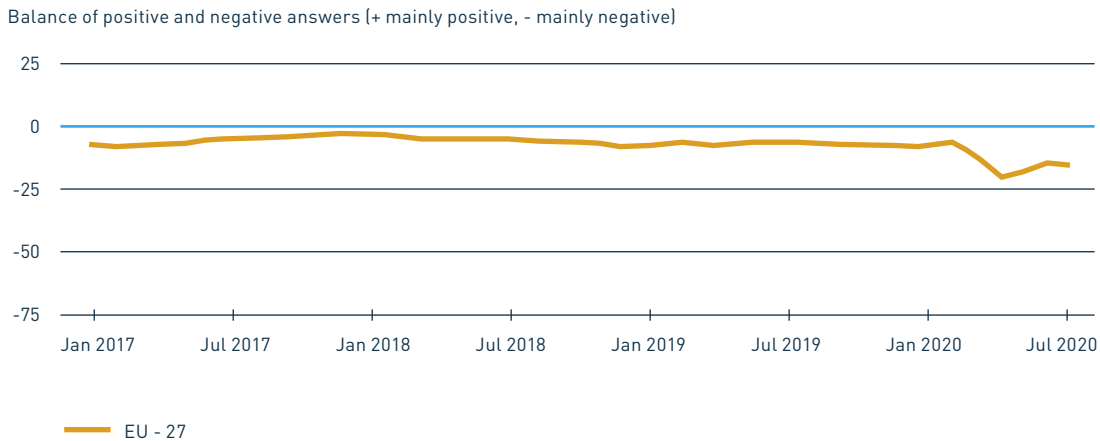


Figure 32. Consumer trust in Europe (Destatis, 2020)

Destatis, a German statistical information source, is consulted to gather information regarding the consumer trust in Europe. Figure 32 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.

### CONSUMER INCOME (17)

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 quantitatively. 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 33, 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.

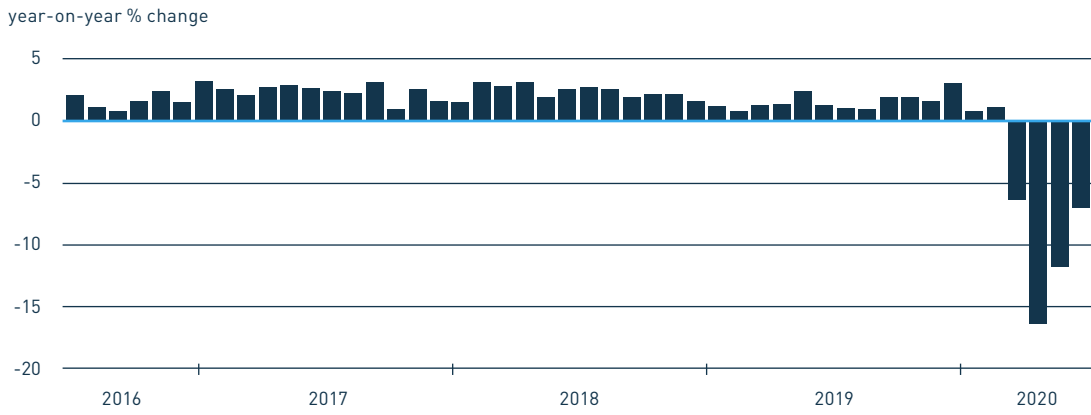


Figure 33. Consumer spending in the Netherlands (CBS, 2020a)

In Figure 34, 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 who are unemployed for less than a year, have increased significantly in Q2 2020 after the Corona pandemic occurred. The number of people that are unemployed for more than a year still decreased 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.

**NUMBER OF PEOPLE AT WORKPLACE (24)**

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.

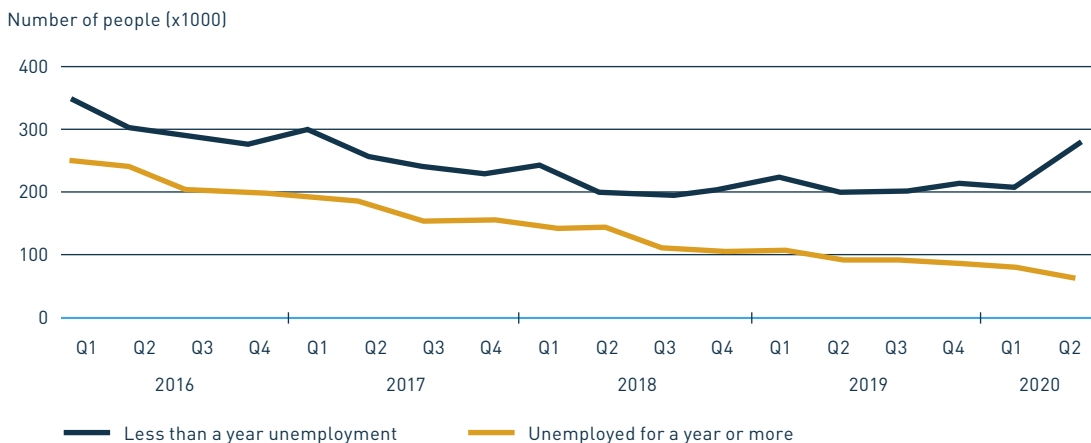


Figure 34. Unemployment figures in the Netherlands (CBS, 2020b)

**ILLNESS PERCENTAGE (25)**

The meaning of the element *Illness percentage* is also 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 quantitatively. 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. Again, 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. In addition, 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 35, 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).

**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 an 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 changes over time.

**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.

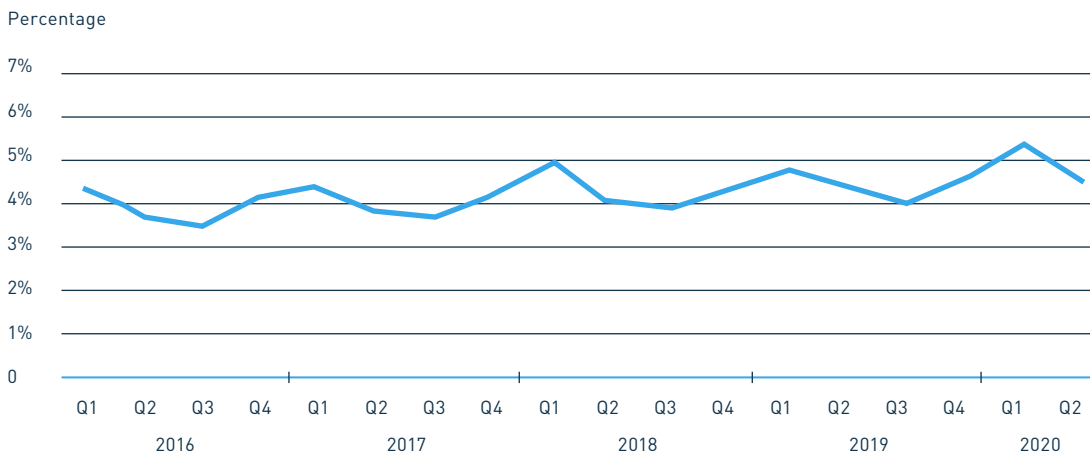


Figure 35. Illness percentage among Dutch employees (CBS, 2020d)

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. On the other hand, the demand and supply forecast should be measured quantitatively. 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 re-scheduling of the operations is possible. This re-scheduling can lead to operations being more reliable. If the desired KPI levels (after re-scheduling) 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 give 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 data, production data, inventory data and supply data. This 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 36 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 36. 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 36, 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.

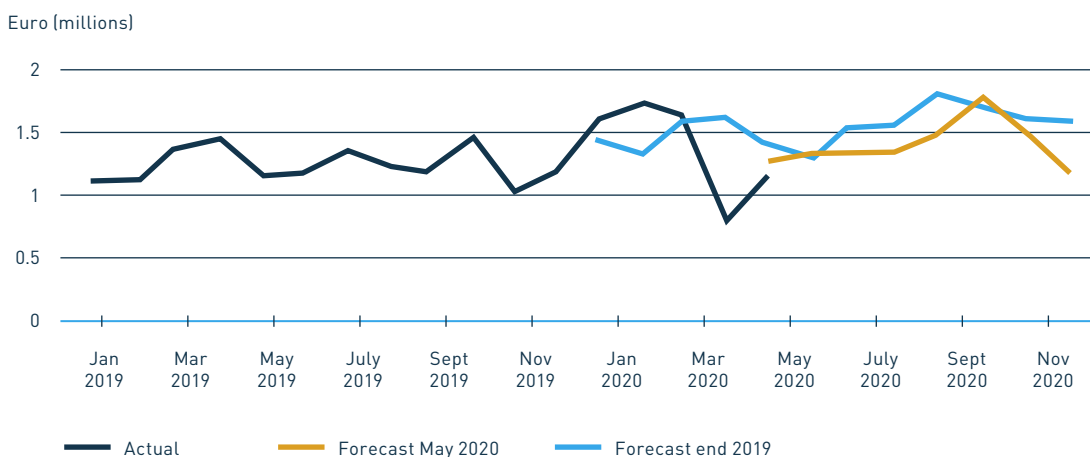


Figure 36. Company Ca Actual vs Forecast Demand



Another aspect that can be checked is the level of inventory. Figure 37 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 B 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.

Company D has made a root-cause analysis for their on-time deliveries to one of their customers. This can be seen in Figure 38. 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 38 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 'Unjustified'. 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.

20/02/2020	Inventory	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12	wk 13	wk 14	wk 15	wk 16	wk 17	wk 18
In	3034										3420	420	420	
Out				1209	403	806	1209	403	403	403	403	403	403	403
Inventory balance		3034	3034	1825	1422	616	-593	-996	-1399	-1802	1215	1232	1249	846

26/02/2020	Inventory	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12	wk 13	wk 14	wk 15	wk 16	wk 17	wk 18
In	2228							1200	420	420	1380	840		
Out					806	403	1209	403	403	403	403	403	403	403
Inventory balance		2228	2228	2228	1422	1019	-190	607	624	641	1618	2055	1652	1249

Figure 37. Inventory balance of one of the suppliers of a supplier of Company B

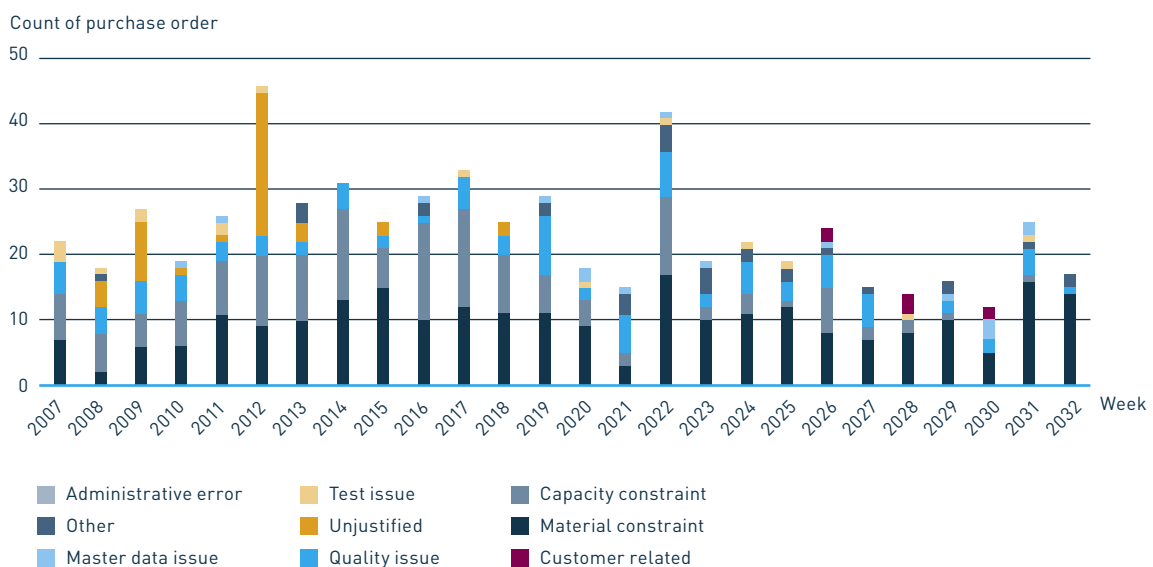


Figure 38. Root cause analysis Company D

**DELAY IN SUPPLY (9)**

The box *Delay in supply* is rather self-explanatory. It concerns whether suppliers deliver their items on time or not, which is an indication for their reliability. This should be measured both quantitatively 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 39), 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 39 it can be seen that during May 2020, which is in the Corona period, the performance of the suppliers significantly dropped to 75.7%.

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 40 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 than 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.

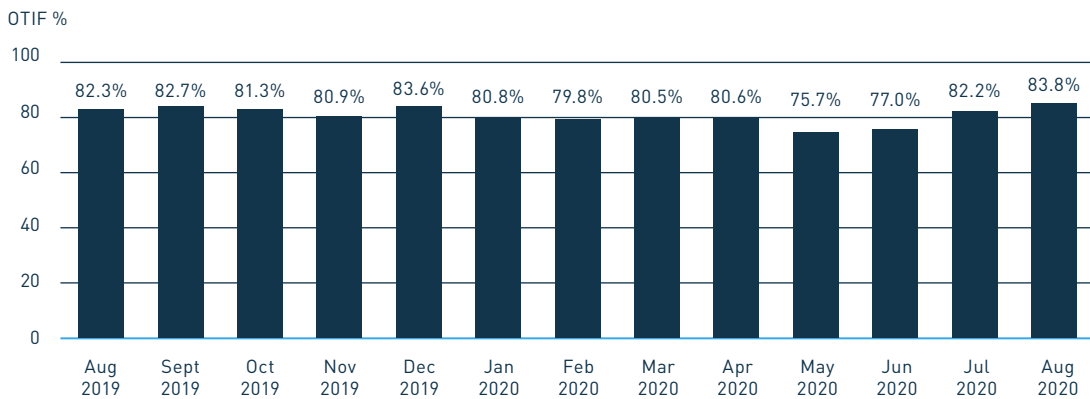


Figure 39. Monthly OTIF performance of all suppliers of Company B

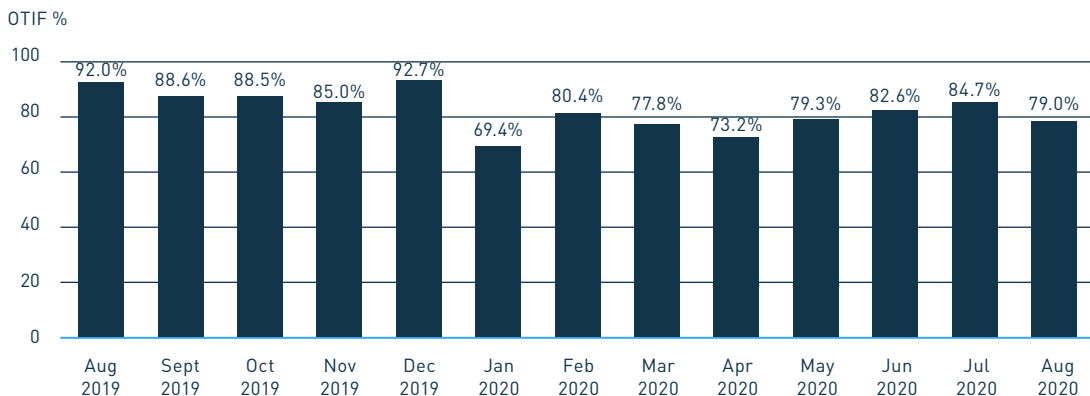


Figure 40. Monthly OTIF performance of one specific supplier of Company B

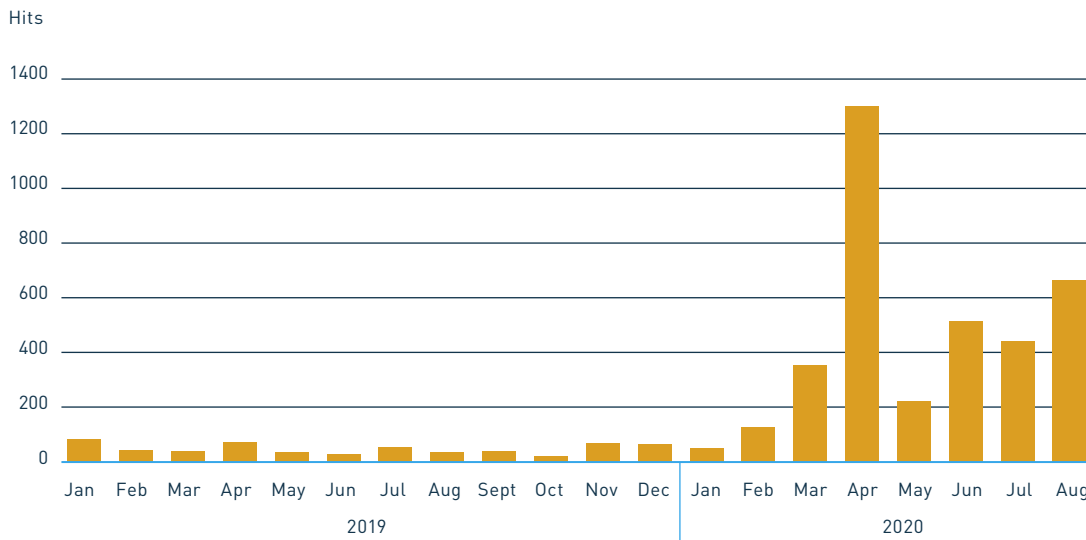


Figure 41. Company B VURO data of one specific supplier

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 41 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.

### 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.

### 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 quantitatively 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 42. 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 43. In Figure 43, a similar trend can be seen as in Figure 42, 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.

Similar as per country, there can also be looked at the number of orders per customer. Figure 44 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.

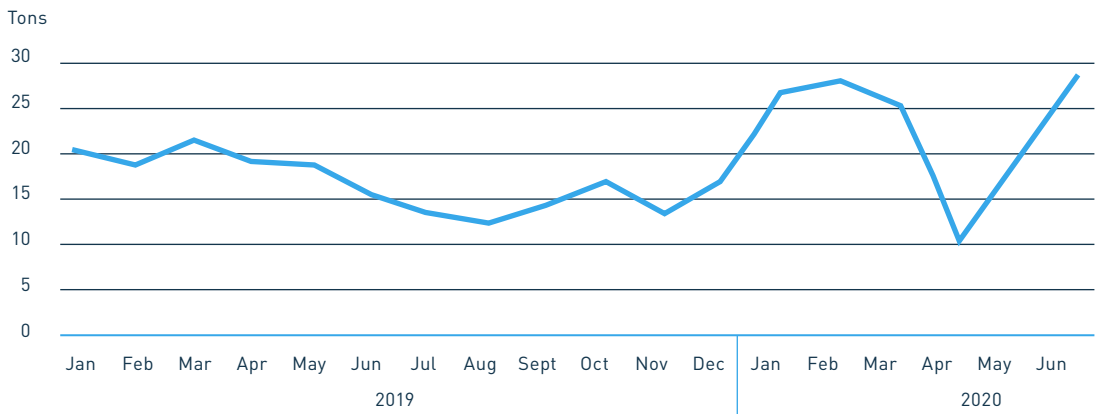


Figure 42. Gross Weight demand Company Ca

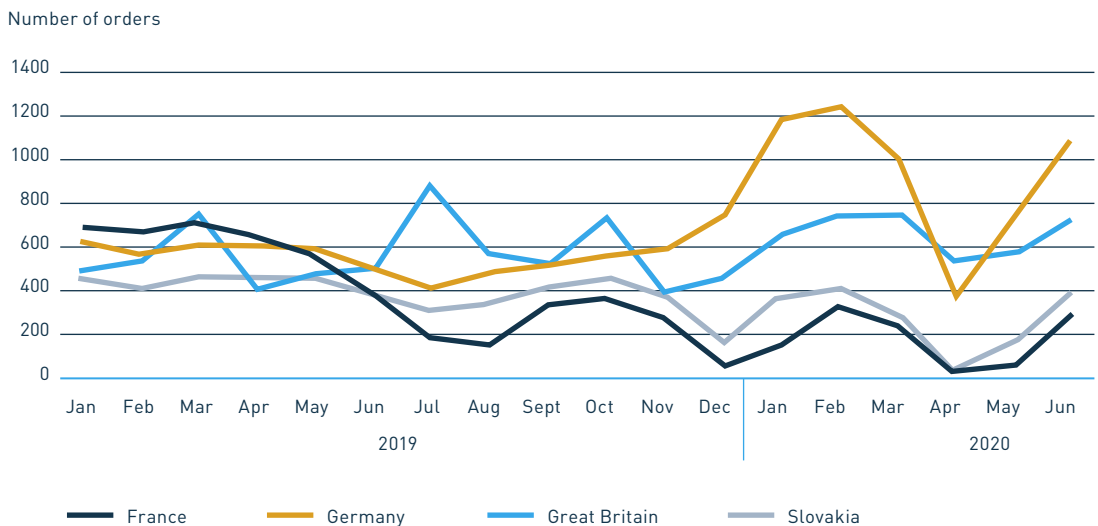


Figure 43. Number of orders per country Company Ca

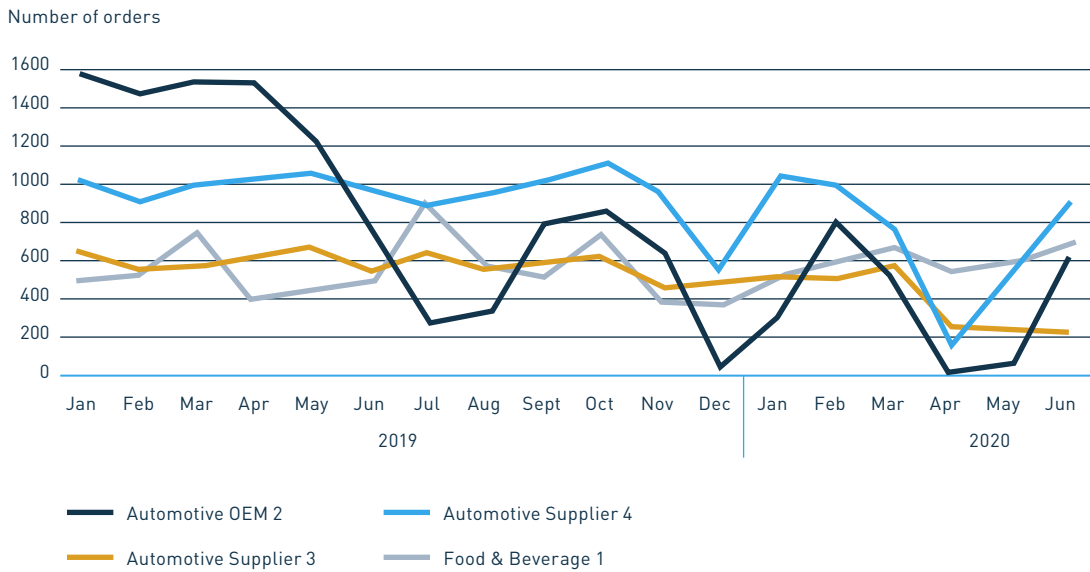


Figure 44. Number of orders per customer Company Ca

**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 quantitatively. 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 45. 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.

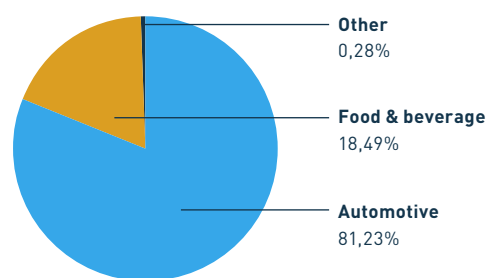


Figure 45. Pie chart of industries in which Company Ca is active

In Figure 45 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 46, 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, and visibility are important factors 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, which can be impacted during a pandemic. 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 quantitatively. 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.

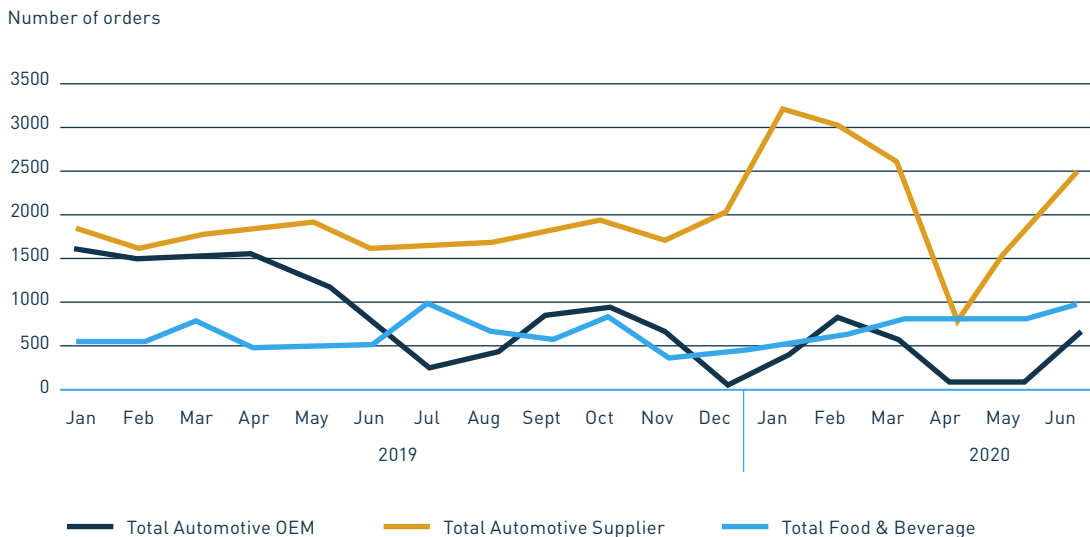


Figure 46. Number of orders per industry of Company Ca

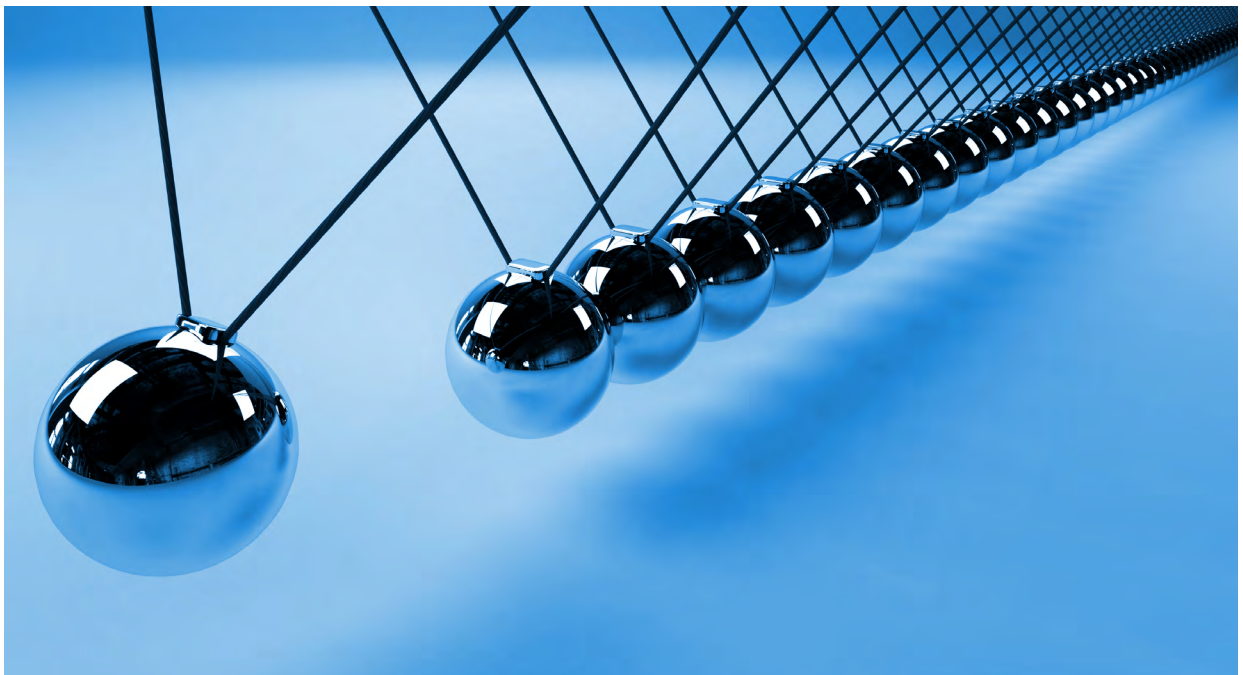


## D

## OBVIOUS RELATIONS IN CAUSE EFFECT DIAGRAM

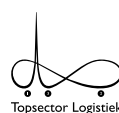
There are some relations in the CE diagram that are rather obvious and do not need any further explanation. These are the following relations:

- 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)



**TKI DIALOG**  
Graaf Engelbertlaan 75  
4837 DS Breda

info@dinalog.nl  
www.dinalog.nl  
+31 (0)76 531 53 00



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