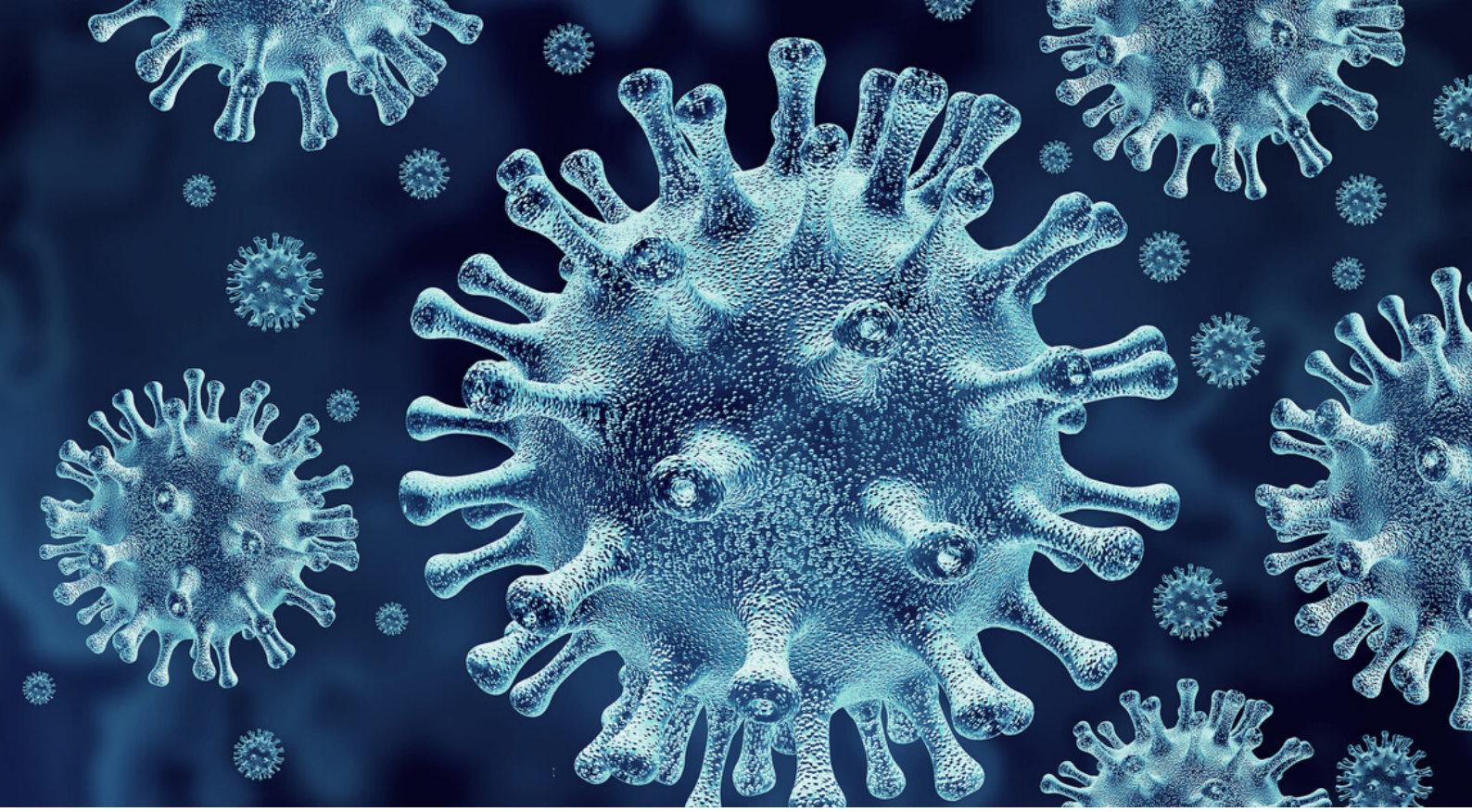

DISRUPTIVE EFFECTS OF COVID-19 ON MODERN SUPPLY CHAINS

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Irene van Linge
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Brecht den Otter
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1. INTRODUCTION

The year 2020 will be remembered for the COVID-19 pandemic and its related consequences. The coronavirus has disrupted global supply chains, posing severe challenges to businesses all over the world. This sudden disruptor has affected every economy, including the ways of living, working, and travelling. Furthermore, it has had a huge disruptive impact on global supply chains. To ensure business continuity, companies have started to reassess the resilience and robustness of their supply chains.

The disruptions have taken place in every industry. However, also positive effects occurred from the pandemic. This paper aims to analyse how companies have responded to changes in supply and demand and to examine what lessons have been learned from this crisis so far.

The pandemic has propelled research in respect to the impact of COVID-19 on the supply chains. The existing literature was a crucial source of inspiration regarding this white paper. The first research that inspired this paper was conducted by students of TU/e (Kok, et al., 2020). This study by the TU/e aimed to provide insights into how the pandemic affected companies and how they reacted to the disruptions caused by the global health pandemic.

Moreover, the study recommended examining the relevance of supply chain visibility to the resilience and robustness of supply chains, focusing on concepts such as disruptions, supply chain robustness, resilience, and visibility (El Baz & Ruel, 2021).

These research studies have served as a steppingstone for this white paper. Yet insights from the industry also contribute to this paper by means of a learning community (LC) named “disruptive effects of COVID-19 and the strive for supply chain visibility.” This LC provides an environment where students, teachers, and professionals from the industry learn together through sharing ideas, feedback, and knowledge.

This white paper focuses on supply chain visibility and its impact on the resilience and robustness of supply chains during the pandemic. Based on the above-mentioned literature, this white paper adresses the following research questions:

1. How and to what extent has the pandemic affected supply chain resilience and robustness?

2. How and to what extent does supply chain visibility influence supply chain resilience and robustness?

2. DATA STUDY

2.1 SURVEY

The objective of this section is to elaborate on the survey as part of the data study. First, the survey and sampling method are described. Then, an elaboration on the tested variables and statistical interpretations is provided. Besides that, comparison between existing literature and personal insights of the researchers has been done.

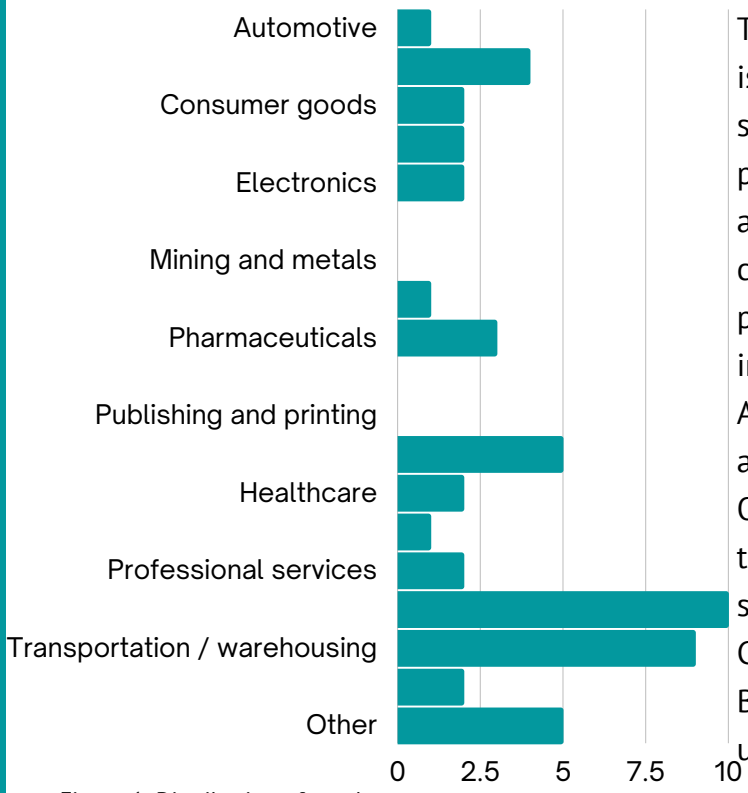

Figure 1: Distribution of employees

The unit of analysis employed in this study is at the level of the industry and logistics service providers and their supply chain professionals. We conducted the survey among national (Dutch) and international companies. We sent the surveys to various professionals in the industry, which include the alumni of Breda University of Applied Sciences and companies that accommodate internships. The database of Osiris-case was used. Additionally, we used the customer relationship management system to contact the network of Logistics Community Brabant. Logistics Community Brabant is a collaboration between universities and professionals which encourages logistic innovations.

In total, 72 respondents answered the survey completely, and these responses were used for the analysis. By analysing the outcomes, indicative conclusions on the interesting and relevant topic addressed in this study can be drawn. These results have served as a steppingstone for the Case Studies in this paper and can also be applied to future research. Figure 1 illustrates how the respondents are distributed among different fields of work. The graph reveals that respondents are working in more than 15 different industries.

The survey consisted of closed-ended questions. These questions were formulated based on prior research. The case study from the TU/e provided the foundation, particularly regarding questions that concern disruptions due to COVID-19. The research executed by Brandon-Jones, Squire, Autry, and Petersen (2014) was used as source of inspiration regarding the understanding of resilience and robustness. Furthermore, the closed-ended questionnaire of the research executed by Mubarik et al. (2021) was a crucial source of information in formulating the survey. The statistical interpretations of our study will also be compared in a later section. To gain a greater understanding of what is happening in the field, input was accessed from the LC. The questionnaire was modified to fit this community.

2.2 SCALES

In the survey, we focused on what happened during the pandemic with respect to a variety of variables: disruptions, resilience, robustness, and visibility. The scales were tested by means of several survey questions, which are provided in appendix 1. Each question contributes to a variable (main topic) and attempts to gain information pertaining to each variable. The measurements allowed us to delineate fine differences between, for example, resilience and robustness or between industries. Furthermore, in setting these variables, we provided a basis to determine precise estimates of the degrees of difference in the relationships among the concepts.

The used scales are reviewed for their reliability using the Cronbach's Alpha test. The results show that the value of alpha for the disruption scale is lower than 0.7, which is the minimum score needed. This means that this scale is not fully reliable and need further research before it can be used in other studies. Appendix 2 provides the complete table with the total rate of Cronbach's Alpha.

To be able to interpret the statistics, it is important to know what the scores per scale mean. The scoring and meaning of the variables are linked to the answer possibilities of the survey.

	Extremely disagree	Somewhat disagree	Agree, nor disagree	Somewhat agree	Extremely agree
Disruptions	Very negative impact of COVID	Slightly negative impact of COVID	No impact of COVID	Slightly positive impact of COVID	Very positive impact of COVID
Robustness	Complete process impacted by COVID	More processtops than procescontinues	Only basic processes could continue	Impact of COVID but within own targets	No impact of COVID
Resilience	No recovery at all	Slow recovery and not optimal	Average recovery time related to industry	Fast and optimal recovery	No recovery needed
Visibility	No insight in the data at all	Insight in 30% of the data	Insight in 50% of the data	Insight in 70% of the data	Insight in all the necessary data
	1 - 1,4	**1,5 - 2,4**	**2,5 - 3,5**	**3,6 - 4,5**	**4,6 - 5**

Figure 2: Scales

2.3 STATISTICAL INTERPRETATIONS

The respondents of the survey were asked about effects on their company and supply chain due to COVID-19 and other variables based on a five-point scale: 1 = extremely disagree and 5 = extremely agree. The middle measurement on the scale corresponds with a neutral response. This approach is known as a Likert scale. The results of the survey are visualized in the histograms attached in appendix 3. The statistical interpretations of the four variables refer to the histograms.

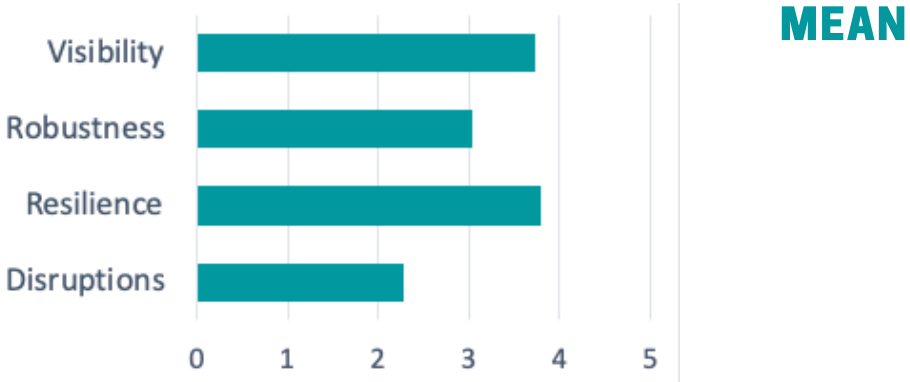

Figure 3: Mean

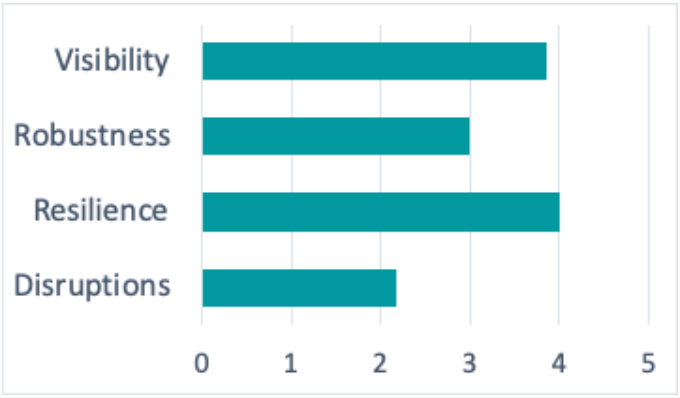

Figure 4: Median

MEDIAN

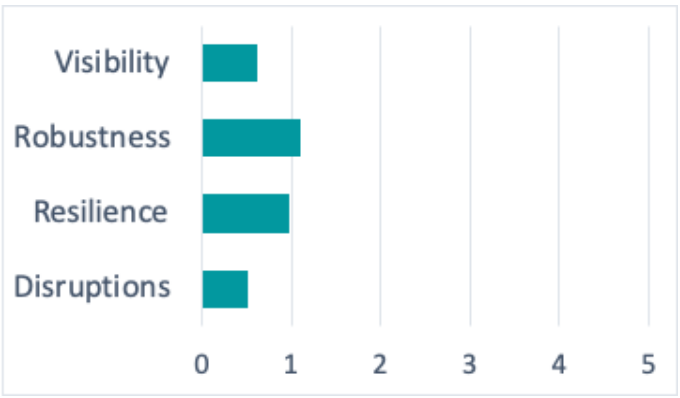

Figure 5: Standard deviation

STANDARD DEVIATION

DISRUPTIONS

Floods, earthquakes, terrorist attacks, and civil unrest are interruptions, natural or human-made, that can cause supply chain disruptions. They differ from a pandemic in that the impact of a pandemic is of a different magnitude and duration (Guan, et al., 2020). Both the magnitude and the duration of the disruption caused by the COVID-19 pandemic differ significantly from that of other disruptions (Ivanov & Dolgui, 2020). This disruption constitutes a major source of uncertainty and equivocality due to the amount of information (Wu, Cegielski, Hazen, & Hall, 2013). The literature shows that disruptions can impact the performance of companies. In particular, the overall performance of an organization may be affected. This can be affected on both financial and non-financial parts of the organization, which is the overall performance. Furthermore, this yardstick can be measured by how well a company is executing its business strategy and can be looked at to identify areas for improvement (Terry, 2020).

The scale of this variable is reverse: a lower score indicates a negative effect, while a higher score indicates a positive effect. The interviewed companies indicated that COVID-19 disrupted their supply chains. 72% percent of respondents scored between 1.7 and 2.8. The results are left skewed, since a score of 3 is neutral. The assumption is that the COVID-19-induced pandemic negatively affected the supply chains of the firms but not catastrophically.

RESILIENCE

The concept of resilience has a broad score. Overall, it refers to the ability to cope with unexpected disruptions of an organization's supply chain and entails the preparedness to respond to disruptions and the way of effectively bouncing back (Barroso & Machado, 2011) (Zsidisin, Panelli, & Upton, 2000). Other researchers have defined resilience as the capability to recover from disturbances within the supply chain in teams of the time needed to adjust (Mitroff & Alpaslan, 2003) (Peck, 2005). In general, companies will use the supply risk management approach to address resilience. However, in this research the concept of resilience is the ability of a firm to bounce back from a disruption. This ability is not binary, it is in what degree a company can recover from a disruption.

83 percent of the respondents scored between a 1.5 and a 4.5. As can be seen in figure 4, the median of resilience is 3. This determines the middle value of the data set. Half of the respondents responded with a value lower than 3, and half of the respondents responded with a value higher than 3. The mean (3.04) has almost the same value as the median. This indicates that supply chain resilience is uniformly distributed, although there are large differences among the firms. Some firms had resilient supply chains during the pandemic, while some did not.

ROBUSTNESS

Due to the increasing volatility in supply chains, robustness has become a more common topic in supply chain management (Christopher & Holweg, 2011). Robustness refers to the extent to which a company is (in)sensitive to external interference. Besides that, robustness is considered as a proactive strategy for a company to cope with disruptions (Chowdhury & Quaddus, 2017). Which content Is also applicable to this study.

After analysing the results, 70% of the respondents scored between 2.8 and 4.8, where a 3 is neutral. As can be seen in figure 3, the mean of robustness is 3.8. Furthermore, the median is 4. These two facts refer to a right-skewed distribution. This means that the supply chains of the firms were somewhat robust during the pandemic.

VISIBILITY

Visibility is another concept that is not clearly defined. However, it can be understood as the ability to trace product materials from their origins (Lee & Rammonhan, 2017). Moreover, visibility can also be defined as the acquisition and evaluation of information within the supply chain to gain control over upcoming risks and to improve decision-making, in order to ultimately improve supply chain productivity (Francis, 2008)(Calatayud, Mangan, & Christopher, 2019). This definition is used in this research. In addition, supply chain visibility enables a company to improve the effectiveness of the whole chain and it reduces the effects of disruptions. It also improves the company's understanding of its partners within the supply chain (Doorey, 2011).

70% of the respondents scored between a 3 and a 4.3, whereas the mean of the respondents is 3.740. The standard deviation of visibility is 0.619. These numbers indicate that the answers of the respondents are closely related. Furthermore, the supply chain visibility of firms is right skewed, which means that the most firms have some insight regarding their supply chains.

2.4 FINDINGS

NOTE: FOR THE HYPOTHESIS, GO TO APPENDIX 4

The findings of the quantitative research can be provided by means of the hyphoteses.

H1: Disruptions > Resilience

The COVID-19-induced disruptions affected the resilience of the supply chains. Approximately 16% of the change in supply chain resilience is explained by the COVID- 19-induced disruptions. The statistical relationship between the COVID-19-induced disruptions and resilience was negative, which means that COVID-19 reduced the resilience of the firms' supply chains. The research paper of El Baz and Ruel determined no relationship between the COVID-19-induced disruptions and resilience.

H2: Disruptions > Robustness

The COVID-19-induced disruptions affected the robustness of the supply chains. Approximately 13% of the change in supply chain robustness is explained by the COVID- 19-induced disruptions. The statistical relationship between the COVID-19-induced disruptions and robustness was negative, which means that COVID-19 negatively impacted the robustness of the firms' supply chains. This corresponds with the literature. The research paper of El Baz and Ruel discovered that the COVID-19-induced disruptions negatively affected the supply chain robustness of firms.

H3: Visibility > Resilience

The hypothesis that visibility influences resilience is not supported. The relation was positive but not statistically significant, so it cannot be accepted. Research papers written by Brandon-Jones et al. and Mubarik et al. determined that visibility improves resilience.

H4: Visibility > Robustness

Visibility positively influences the robustness of the supply chain; approximately 6% of the degree of robustness can be explained by supply chain visibility. This aligns with the literature. The research papers written by Brandon-Jones et al. and Mubarik et al. discovered that visibility improves robustness.

3. CASE STUDIES

The survey results alone are not enough to draw sufficiently substantiated conclusions. The analysis of the qualitative research focuses on the "how" for both questions. While statistical conclusions can be drawn from the survey results, the case studies will provide an in-depth analysis by looking at different perspectives.

3.1 VARIOUS PERSPECTIVES

In order to outline perspectives on the addressed topic, five interviews were conducted. Differences between the companies were noted with respect to the variables of resilience, robustness, and visibility.

For the purpose of this white paper, the researchers have interviewed a global reliability engineer, who represented one of the three largest companies in the world (company A). Some similarities in answers were noticed between this interviewee and the general manager of a German trading company, that is active in the chemicals and raw materials industry (company B). Insights were also obtained from a representative of a logistics service provider (company C). Furthermore, insights are gained from the perspective of healthcare (company D). Finally, the founder of a Dutch interior brand (company E) that is mostly managing operations in the downstream of the supply chain was interviewed.

Disruptions

The pandemic has hit all participants, however, they were not all equally impacted by the disruptions. The major challenge for both organizations operating within the chemical industry was the unavailability of raw materials. Unforeseen disruptions arose from every corner, which made managing logistics a challenge. In addition, company A mentioned that there were challenges in keeping the factories operating because of the unavailability of people due to infection rates. Company C had a similar problem, where they had a shortage of workers, due to sick leave.

Company D is active in the health care sector, meaning that its work process continued during the whole period of the pandemic. However, the company experienced some effects related to their process what needed to be adjusted to be effective and productive during this period. This lies in contrast to the experience of Company E, which experienced a demand collapse of 60% in March/April 2019.

> *"As you order something on one day, the next day it has become unavailable because disruptions came out of every corner"*

Resilience

Despite of the enormous demand drop company E experienced, the company decided to continue production, which resulted in high inventory levels. After the first ware, the end customer was used to the lockdown and began purchasing again, which resulted in increasing demand. The interior brand has experienced to be resilient during the pandemic. This had partly to do with keep running the productions and the fact that their end consumers were resilient and started to proceed with life during the pandemic. Moreover, the healthcare sector (company D) had to adjust to many changes within their field. Therefore, company D adopted a new way of working and experienced a transition from physical to digital direct care.

"Our company was very robust, because we did not need much resilience"

Robustness

Both companies operating in the chemical industry (company A and B) were not confronted with significant demand drops. This resulted in business being able to continue. Therefore, both organizations relate to being robust because of their position within the supply chain. Company D was also able to continue their operations. This was partly due to the sector in which the company is operating.

Visibility

All participants mentioned that visibility both within and outside their company is crucial for managing their operations. Company A mentioned that the degree of transparency and sharing information with direct partners is sufficient. However, further down the supply chain the degree of visibility is lacking due to the limited transparency between entities. For example, information on ETA's were often not reliable.

According to company D, supply chain visibility accompanies trust and integrity, which ensures that supply chain visibility has an influence on handling disruptions to a certain extent. Therefore, the interviewee stated that visibility is associated resilience. However, the importance of visibility in times of a pandemic. Company B, mentioned that whether there is visibility or not, it does not always make up for the disruption a company is facing.

"But the visibility wasn't helping me; the container was still at the harbour standing still"

3.2 FINDINGS

The pandemic has caused disruptions which affected all companies participating. However, they were not all equally hit by the disruptions. The researched have seen that the degree of disruptions are dependent on where a company is located within the supply chain. This position within the chain and sector in which a company operates also lead to differences concerning the degree of resilience and robustness. Visibility throughout the supply chain is embraced by all business leaders; however, in practice, it is not widely adopted. Visualizing can help organizations significantly adapt to crisis situations, such as a pandemic. Moreover, it supports companies to be more prepared and resilient in times of crisis. This conclusion contradicts to the not supported relationship between the relationship of visibility and resilience. However, it supports the statement that visibility is not the end solution whilst being in a pandemic.

3.3 LESSONS LEARNED

Altogether, it is important for companies to learn from the COVID-19 pandemic so that they can make better decisions when a similar situation occurs again. The companies have explained the lessons they learned from the COVID-19 pandemic which resulted from both positive and less positive decisions made by the companies. Some examples are:

- Keep the process going to prevent the economy from coming to a standstill.
- Do not act immediately but take time to analyse the situation and its consequences to make better decisions.
- Keep the internal communication line between employees clear and short, so that everybody within the company knows what to do and how to do it.

4. CONCLUSIONS

After having analysed both the data and the case studies, the following conclusions were drawn. These conclusions refer to the research questions that are stated in the introduction.

1. How and to what extent did the pandemic affect supply chain resilience and robustness?

Regarding the first research question, we compared the results of this study to the findings of the study of El Baz and Ruel (2021). They did not find a relationship between COVID-19-induced disruptions and resilience. The results of the quantitative part of this white paper state a negative statistical relationship between these two variables. Furthermore, the relationship between disruptions and robustness is also negative. The COVID-19 pandemic affected the supply chain in multiple ways, such as the need to change work processes, but also the fact that the demand for products fluctuated between significant increases and significant decreases. Despite the significant impact that the pandemic has had on global supply chains, organizations generally believe that they will be able to recover and meet their old supply chain performance levels. By means of the case studies, the researchers observed that the extent of being resilient or robust during a pandemic is more complex than a statistical relationship implies. Variables such as industry and position within the supply chain influence the degree of resilience and robustness of the firms.

2. How and to what extent does supply chain visibility influence supply chain resilience and robustness?

With the second research question, we distinguished between the variables of visibility, resilience and robustness. The findings of the quantitative research imply that there is no relationship between visibility and resilience; however, there is a relationship between visibility and robustness. From this analysis, the researchers reached the conclusion that, when there is visibility along the supply chain, firms are more likely to stand up to the high pressure of disruptions. The result of visibility not being related to resilience lies in contradiction to the studies of Brandon-Jones et al. (2014) and Mubarik et al. (2021). Besides that, the case studies also suggest that companies embrace supply chain visibility in times of a crisis is not the end solution for being resilient during a pandemic after all. Furthermore, the relationship between visibility and robustness aligns with the literature, where the consensus is that visibility improves robustness (El Baz & Ruel, 2021) (Brandon-Jones et al., 2014), although the case studies suggest that being robust is difficult to clarify, since the COVID-19 pandemic took place throughout the whole supply chain.

IMPLICATIONS

The pandemic had a substantial effect on the supply chains of the firms. The pandemic impacted both the resilience and the robustness of their supply chains. The qualitative analysis and quantitative analysis support that, the literature also supports that.

Encouraging companies to improve visibility will contribute to supply chain robustness, which enables companies to withstand disruptions like COVID-19. Robustness refers to the ability of firms to be unaffected by disruptions.

There is no relation found between visibility and resilience in the quantitative analysis. However, this is in contrast with the literature. The literature states that visibility has a positive influence on resilience. Furthermore, the firms did not expect visibility to be the critical factor in mitigating the disruptions.

Altogether, the degree of the tested variables was in line with the literature this white paper is based upon. There is a contradicting result in the relationship between visibility and resilience with the literature and thus the expectations of the authors. Overall, the insight of this study has provided indicative insights on how the pandemic has affected companies.

Finally, we would like to thank our respondents for their contribution to our quantitative research. We also want to express our appreciation to all the interviewees for sharing their experiences from the field. Last but not least, the learning community including the lecturers and professionals, for expressing enthusiasm towards their expertise and their critical eye.

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6. APPENDICES

APPENDIX 1. SURVEY QUESTIONS

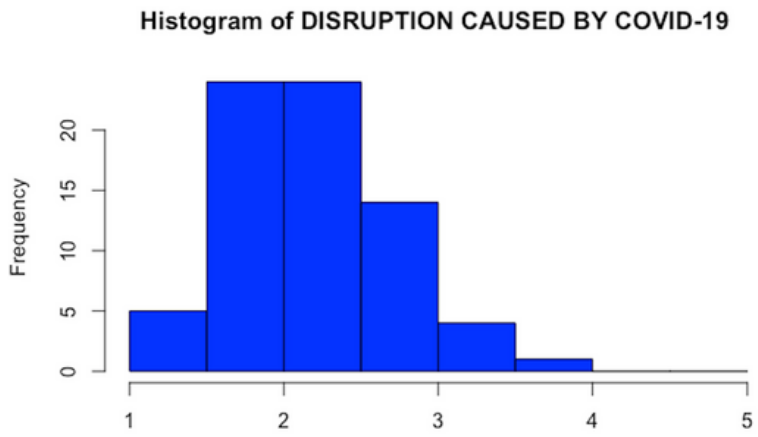
Topic	# Question	Main topic question	Sub-question
Disruptions	2.2	Performance COVID-19	1 Customer satisfaction.
			2 Delivering value to customers.
			3 Delivering what customers want on time.
			4 Retaining valued customers.
			5 Market share growth relative to competitors.
			6 Growth in revenues.
			7 Acquiring new customers
			8 Increasing revenues of existing customers.
	2.3	Actual performance COVID-19	1 Overall efficiency of operations.
			2 Lead time – delivery to customers.
			3 Lead time – by contractors and/or suppliers.
			4 Purchasing costs.
			5 Availability of human capital.
			6 Availability of physical assets.
Robustness	2.4	Robustness	1 Operations were able to continue.
			2 We were still able to meet customer demand.
			3 Performance met (or even exceeded) targets.
			4 The supply chain of which we are part of was still able to carry out its regular functions.
Resilience	2.5	Resilience	1 Material and/or transport flow was quickly restored (or never affected).
			2 It did not take long to recover normal operating performance.
			3 The supply chain of which we are part of easily recovered.
			4 Disruptions were dealt with quickly.
Visibility	3.3	Demographic visibility	1 Our major customers share their point of sales information with us.
			2 Our major customers share their demand forecasts with us.
			3 Our major customers share their inventory level information with us.
			4 Our major customers share their promotional plans with us.
	3.4	Supply chain visibility	1 Our major supply chain partners share inventory level information with us.
			2 Our major supply chain partners provide us with advanced shipment notice.
			3 Our major supply chain partners share information with us about order lead times/delivery dates.
			4 Our major supply chain partners provide us with location and product status information.

APPENDIX 2. CRONBACH ALPHA RATE

Variables	Cronbach Alpha rate	(Not) Accepted
Competitve advantage	0.836	Accepted
Disruption	0.674	Not great
Resilience	0.822	Accepted
Robustness	0.855	Accepted
Transparency	0.749	High enough
Visibility customer	0.799	Accepted
Visibility supply chain	0.799	Accepted
Visibility information	0.627	Not great

APPENDIX 3. HISTOGRAMS OF CONCEPTS

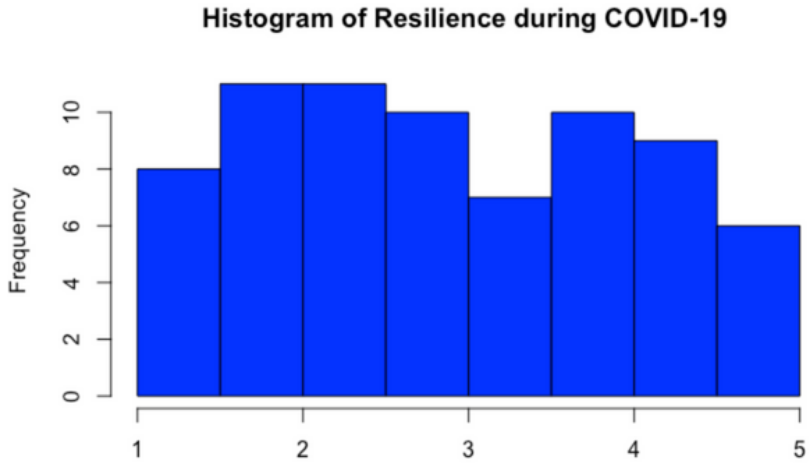
DISRUPTIONS



Statistics

Variables	72
Mean	2.278
Median	2.167
Standard deviation	0.5028345
-1 sd	1.77
+ sd	2.78

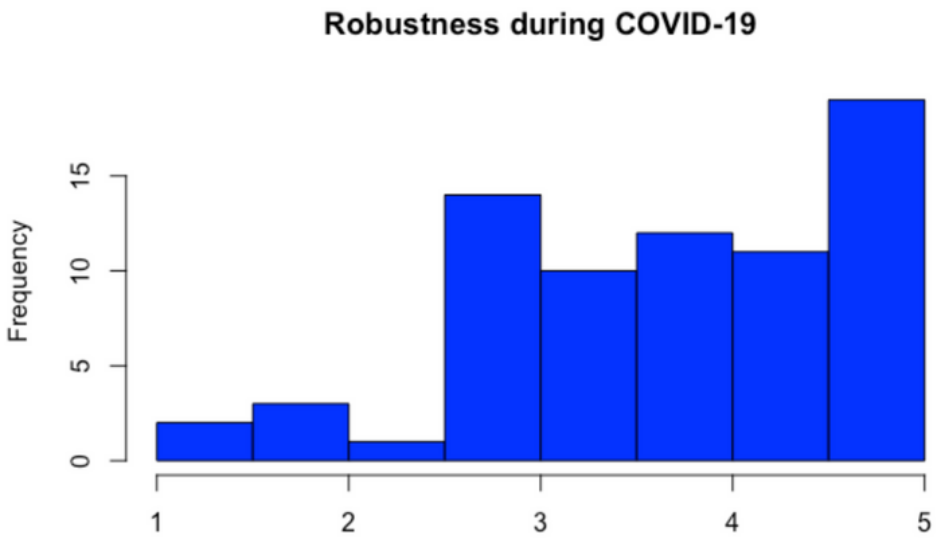
RESILIENCE



Statistics

Variables	72
Mean	3.042
Median	3
Standard deviation	1.094963
-1 sd	1.95
+ sd	4.14

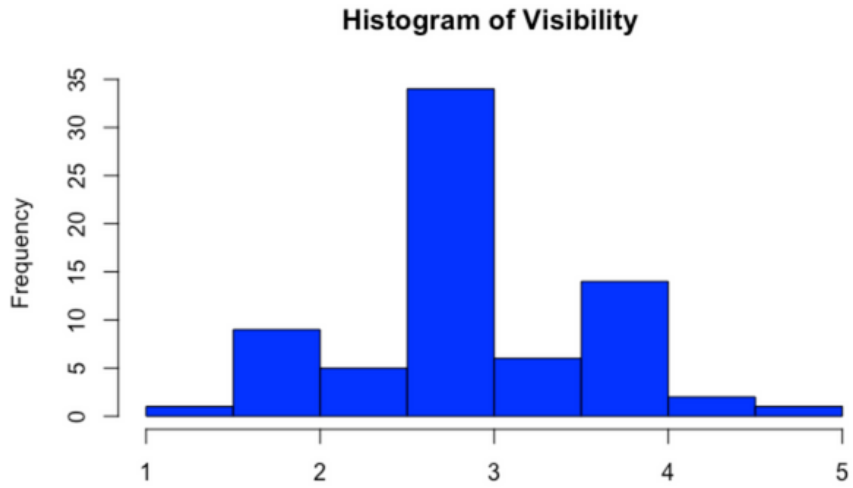
ROBUSTNESS



Statistics

Variables	72
Mean	3.795
Median	4
Standard deviation	0.9717184
-1 sd	2.83
+ sd	4.79

VISIBILITY



Statistics

Variables	72
Mean	3.740
Median	3.857
Standard deviation	0.6193797
-1 sd	3.12
+ sd	4.36

APPENDIX 4. HYPOTHESES

Based on the conceptual model, there are four hypotheses formulated.

To answer the first research question, the following hypotheses are formulated.

H1 The covid-19 induced disruptions affected the supply chain resilience
H2 The covid-19 induced disruptions affected the supply chain robustness

To answer the second research question, the following research questions are formulated.

H3 Visibility influences supply chain resilience
H4 Visibility influences supply chain robustness

APPENDIX 5. STATISTICAL ANALYSIS OF RELATIONS

Hypothesis

DV	IV	P-Values	R-Squard	Coëfficiënt	Result	Relation
Disruption	Robustness	0.001771	0.131	-0.1885	Supported	Negative
Disruption	Resilience	0.0005692	0.157	-0.1831	Supported	Negative
Visibility	Robustness	0.04271	0.057	0.1845	Supported	Positive
Visibility	Resilience	0.657	0.003	0.0364	Not Supported	Positive