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A Manufacturing Industry Perspective on Pandemic-Induced Supply Chain Disruptions

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Abstract: This study explores the impact of COVID-19-related supply chain disruptions on manufacturing firms, focusing on external risks: demand, environmental, and supply. Our literature review reveals the general lack of comprehensive disruption plans and exposes the vulnerabilities in manufacturing firms with limited research addressing this issue. By adopting an interpretive research philosophy and a qualitative, inductive approach, our research delves into the operational challenges and adaptations implemented in the manufacturing sector during the pandemic through case studies. The findings reveal that COVID-19 significantly increased risks, causing demand surges, logistical disruptions, extended lead times, and labour shortages due to lockdowns, necessitating strategic shifts towards localised and digital supply chains in the manufacturing sector. Our study not only enriches the supply chain literature by detailing the pandemic's effects and emphasising the need for robust disruption plans for enhanced resilience but also offers new insights into managing supply chain disruptions in crises, highlighting the necessity of strategic adaptations for future crisis preparedness across various industries.

Keywords: COVID-19 pandemic; supply chain disruption; manufacturing firms; business operations

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1. Introduction

In March 2020, the declaration of COVID-19 as a global pandemic by the World Health Organization (WHO) notably disrupted the world economy (Odunayo & Victor, 2020). A report from Fortune (2023) indicated that the pandemic could permanently alter supply chains, propositioning a shift from global to local supply chain networks, increased reliance on technology, and a strategic transition from lean and just-in-time to responsive and just-in-case supply chain models. This situation has created new avenues for exploring supply chain disruptions (Moncayo, 2022; Shih, 2020). Shen and Sun (2021) categorise COVID-19 as an infrequent yet highly impactful event on business operations, causing unparalleled disruptions. This perspective is supported by Kähkönen et al. (2021), who observed that COVID-19 has introduced novel and unforeseen operational challenges for firms, thus opening avenues for groundbreaking research to assess these effects.

Pandemic-related disruptions and supply chain risks have been studied by various researchers, with both the short- and long-term effects assessed across different countries (Ivanov, 2020; Queiroz et al., 2020; Hohenstein, 2022; Shahbaz et al., 2019; Karamoozian et al., 2024). Our research reveals the important role of resource optimisation, distribution, and the effective management of logistical risks in mitigating disruptions and ensuring

greater supply chain resilience. However, there is limited research addressing preparedness and the need for a robust disruption management plan to handle COVID-19-like disruptions, including an unsustainable surge in demand, insufficient stock levels, and supply chain delays. Our study aims to comprehensively investigate the supply chain disturbances caused by COVID-19 and its impacts on the operational functions of manufacturing firms. It seeks to fill a research gap that has typically been focused on the technological aspects and resilience of supply chains in the manufacturing sector, as identified and revealed by Ardolino et al. (2022). Our research delves into the risks and disruptions in supply chains within a manufacturing context, examining how these disturbances affect operational activities. This study seeks to identify the external supply chain risks posed by COVID-19 to manufacturing firms, understand the influence of COVID-19-related supply chain disruptions on a manufacturing company, and explore how these disruptions impact firms' operations. We will also examine the operational difficulties faced by manufacturing firms during the pandemic, encompassing issues such as workforce shortages, breakdowns in supply chain communication, and logistic challenges, which we categorise as operational risks (Vafin, 2021).

Conducted during a period of significant supply chain upheaval, this study seeks to achieve the following research objectives. First, we will identify and understand the various external risks that manufacturing firms have faced in their supply chains during the COVID-19 pandemic. This objective seeks to explore the range and nature of challenges that emerged externally, such as logistical issues, supplier disruptions, or market changes, which have directly impacted these firms. Second, this study intends to examine the specific impacts of COVID-19-related disruptions on the operations of a manufacturing firm. This involves a detailed analysis of how these disruptions have altered firms' supply chain dynamics, including changes in supply chain strategies or responses to unexpected disturbances. Lastly, this study seeks to delve into the operational activities of a manufacturing firm and ascertain how they have been affected by the supply chain disruptions caused by the pandemic. This will involve investigating the direct consequences of these disruptions on the firm's day-to-day activities, from production to distribution and beyond. Employing a case study approach will allow us to develop an in-depth exploration of these objectives (Yin, 2012).

Section 2 of this paper conducts a comprehensive literature review examining previous research on supply chain risks and disruptions. This section identifies the types of risks firms face, with particular emphasis on those stemming from the COVID-19 pandemic. After pinpointing these risks, it then explores the resulting supply chain disruptions by analysing previous research in this area and develops a theoretical framework to assess the impact of COVID-19 disruptions on manufacturing firms. Section 3 elaborates on the research methodology utilised in this study, adopting a qualitative approach through in-depth case studies. Semi-structured interviews were conducted with employees involved in the supply chain of a manufacturing firm, aiming to gain industry-specific insights into the impact of supply chain disruptions on operations. Section 4 analyses the interviews and presents our findings, aligning them with those arising from the literature review and identifying both existing and emerging themes. Section 5 draws conclusions from the research and discusses research limitations. Future research directions are also suggested.

2. Literature Review

This section examines the relevant literature on supply chain risks and disruptions, particularly under the influence of the COVID-19 pandemic. It discusses various viewpoints on supply chain risks, contrasting the views of Wagner and Bode (2008), who see risks as both harmful and potentially opportunistic, with those of Chang et al. (2015) and

Baryannis et al. (2018), who focus on the negative impacts of risks. Our literature discussion follows a systematic approach, categorises the risks into internal and external types, and assesses how the pandemic has exacerbated external risks like demand, environmental factors, and supply risks. This section also reviews frameworks for managing supply chain disruptions, highlighting contributions from Macdonald and Corsi (2013) and Magableh (2021) and discusses the amplified ripple effect in supply chains during COVID-19. This comprehensive review aims to understand the impact of these risks and disruptions on the operations of manufacturing firms during the pandemic.

2.1. Supply Chain Risks

The concept of supply chain risks is multifaceted in the literature. Wagner and Bode (2008) describe these risks as double-edged, representing potential dangers with adverse outcomes and opportunities. This contrasts with Chang et al. (2015) and Baryannis et al. (2018), who characterise supply chain risks as having predominantly negative consequences, such as damage or loss, disrupting the continuity of supply chains. Accordingly, this study adopts a perspective that acknowledges how supply chain risks can lead to both positive and negative effects on organisations within the supply chain. Manuj and Mentzer (2008) discussed eight types of risks, including supply, operational, demand, security, macro, policy, competitive, and resource risks. However, this study reveals that besides risks residing in supply, operations, demand, and security are among the most impactful areas for the supply chain. Wagner and Bode (2008) categorised risks from five different sources, with an emphasis on demand and supply risks. Remko (2020) added to this by including control risk as a significant supply chain risk. Given that COVID-19 represents an external disruption, this research aims to examine how the pandemic has intensified external supply chain risks, including the demand, environmental, and supply risks which are generally the three main external supply chain risks, confronted by firms.

Supply chain risks are typically classified into two types: internal and external. Shahbaz et al. (2019) defined internal risks as those linked to a company's operational activities. Operational risks associated with common challenges like extended lead times and fluctuating demand contrast with disruption risks, which, though infrequent, have significant impacts. Various operational risks have been identified and assessed in the literature. Butt (2021) discussed various risks, including delays in supply chains, systems, forecasting errors, intellectual property, procurement, inventory, and capacity. Further risks were also suggested in this study, for instance, in the form of delays in stock replenishment, machine malfunctions, and subpar final products. Research by Chodakowska et al. (2024) focused on transport risk management during COVID-19. Through the use of a quantitative risk assessment model, this research assessed the risk interdependencies enhancing transportation resilience.

External risks arise from external and disruptive events. Disruption risks can severely affect supply chain operations; for example, when factories or transportation links break, the whole supply chain becomes inoperative and disrupted. Pandemics, as classified by Ivanov (2020) and Baz and Ruel (2021), represent a unique type of disruption risk, starting small and escalating rapidly across regions, unlike typical disruptions such as natural disasters or strikes. Rahman et al. (2023) examined global supply chain vulnerabilities during the COVID-19 pandemic, addressing panic-buying and sudden surges in demand in particular. The authors found that to address this issue, decentralised manufacturing to multiple suppliers and partnering with third-party transporters can mitigate the effects of panic-buying, ensuring the higher output and availability of essential goods. Table 1 presents how COVID-19, as an external factor, exacerbated these risks for businesses.

Table 1. COVID-19 as a disruptive factor, exacerbating external risks for business's supply chains.

Demand risks	These risks involve disruptions in the downstream supply chain, encompassing outbound logistics like physical product distribution to the end consumer. Typical issues include transportation delays and product demand fluctuations determined by customer preferences.
Environmental risks	These are risks beyond a firm's control and include a variety of disruptions. Political factors like government-imposed lockdowns, natural occurrences such as the COVID-19 pandemic itself, and social factors like terrorist attacks fall under this category.
Supply risks	These are the disruptions in the upstream part of a supply chain, involving the uncertainties associated with supplier activities and overall supplier relationships during the period of COVID-19. Critical issues include variability in supplier lead times, reliability issues, and interruptions in the supply of resources to the primary firm.

The effects of supply chain risks on supply chain management during COVID-19 have been studied by numerous researchers over the last few years. Ivanov (2020) developed a simulation model to forecast the pandemic's short-term and long-term effects on supply chains, identifying the timing of facility operations in various countries as a critical determinant of impact. Complementing this, Queiroz et al. (2020) examined the effects of COVID-19 on supply chains and proposed a framework encompassing six areas: adoption, digitalisation, preparedness, recovery, ripple effect, and sustainability. Their conclusion emphasised the paramount importance of optimising resource allocation and distribution during such disruptions. Hohenstein (2022) further highlighted the logistical risks posed by the COVID-19 pandemic, underscoring logistics as a vital element in risk management; any disruption here can rapidly debilitate the entire supply chain (Shahbaz et al., 2019). However, there seems to be a gap in the literature concerning the specific impacts of these risks on business operations. Bani-Irshid et al. (2024) explored supply chain resilience and identified the key risks affecting manufacturers. It emphasised sustainability and proactive risk management to enhance supply chain stability. Supply chains are inherently prone to various interconnected risks, each potentially amplifying the impact of others. Firms must be aware of these risks, as their occurrence can lead to significant disruptions.

2.2. Supply Chain Disruptions

Craighead et al. (2007) defined supply chain disruptions as unforeseen events interrupting the flow of goods and materials in a supply chain, leading to operational and financial risks for businesses. Baghersad and Zobel (2021) concur with this, defining disruptions as any hindrance to the flow of materials, information, or services to the end consumer, which can be seen as the actualisation of supply chain risks. Vafin (2021) elaborates on operational risks, which are everyday challenges affected by disruptions, with the COVID-19 pandemic causing specific issues like labour shortages (Causa et al., 2022), transportation delays (Morris, 2022), and communication barriers (Kyslyy et al., 2021), all leading to significant disruptions.

The topic of supply chain disruptions has been extensively researched, especially in the context of the pandemic. Before the COVID-19 pandemic, frameworks like the one by Macdonald and Corsi (2013), which categorise disruptions into events, disruption management, and performance, were established. These frameworks analyse the causes of disruptions, how firms discover and recover from them, and assess their performance in responding to them. Despite being pre-pandemic, these theories remain relevant for analysing COVID-19 pandemic disruptions. Pujawan and Bah (2021) suggest adapting these frameworks to include digitalisation and supply chain localisation in response to the COVID-19 pandemic.

Magableh (2021) proposes a framework specific to the COVID-19 pandemic's impact on supply chains, dividing it into interconnected factors like demand volatility, supply disruptions, and governmental responses. This framework complements Macdonald and Corsi (2013) by providing factors leading to COVID-19 pandemic disruptions and offering a means to evaluate a firm's performance in response to these disruptions.

The risk of disruptions affects both upstream and downstream supply chains, as Craighead et al. (2020) noted, with the COVID-19 pandemic causing significant shifts in supply and demand. While Peck (2003) points out that supply risks impact the upstream and demand risks affect the downstream, Ivanov (2020) emphasises the interconnectedness of these risks. The 'ripple effect', or as Dolgui and Ivanov (2021a, p. 2) call it, the 'domino effect', illustrates how disruptions cascade through the supply chain. This effect was particularly pronounced during the COVID-19 pandemic, as shown by Scarpin et al. (2022) in their study on the airline industry.

This study utilises an adapted version of Macdonald and Corsi's (2013) Event, Discovery and Recovery, and Performance framework, integrated with Magableh's (2021) Impact on Supply Chains framework, to analyse the effect of the COVID-19 pandemic on the operational activities of a manufacturing firm. This approach provides insights into the effectiveness of a firm's resilience strategies during the pandemic.

3. Methodology

In this research section, we delve into the methodologies and ethical considerations essential for conducting a comprehensive study on the impacts of COVID-19 pandemic-related supply chain disruptions in a manufacturing firm. Guided by Saunders et al.'s (2016) insights into research philosophy, this study adopted an interpretivism approach and an inductive theory development process to gain a nuanced understanding of the subject matter. A combination of qualitative methods, primarily semi-structured interviews, was employed for data collection to capture the depth and diversity of experiences of various employees within the firm. This approach was substantiated using a purposive sampling method, ensuring that participants directly involved in the supply chain were selected for their relevant insights. This study follows Braun and Clarke's (2022) structured thematic analysis to systematically identify and analyse emerging themes from the interview data, underpinning the research with rigour and depth. Additionally, the research design encompassed stringent ethical considerations, including informed consent and participant confidentiality, adhering to the guidelines set by Liverpool Hope University, and ensuring the integrity and ethical soundness of the study. This methodological framework sets the stage for a detailed exploration of how the COVID-19 pandemic has reshaped supply chain dynamics in the manufacturing industry.

3.1. Research Design

In this study, the research philosophy adopted was grounded in the interpretivism approach, as detailed by Saunders et al. (2016, p. 124) and Alharahsheh and Pius (2020). This approach is underpinned by a set of beliefs and assumptions about knowledge development, emphasising the subjective interpretation of cultural, contextual, and circumstantial factors. Specifically, this research sought to delve into the nuanced impacts of the COVID-19 pandemic on supply chain disruptions within a manufacturing firm, and interpreting various perspectives and experiences of the firm's employees was crucial. This approach aligns with interpretivism's focus on understanding phenomena within specific contexts rather than making broad generalisations.

The research methodology employed was inductive, as described by Saunders et al. (2016). This inductive approach is essential to build upon the existing literature—such as

the works of Baz and Ruel (2021), Magableh (2021), and Craighead et al. (2020)—and to develop a deeper understanding tailored to the manufacturing industry, which has not been extensively covered in previous studies.

Regarding the methods used, this study relied on qualitative research, following the definition provided by Strauss and Corbin (1998) and supported by Fischer and Guzel (2022, p. 2). Qualitative research methods were chosen over quantitative methods for their ability to capture rich, detailed data beyond numerical statistics. While quantitative research, as described by Collis and Hussey (2003), offers precision and numerical insights, it lacks the depth and personal perspectives that qualitative methods provide. Consequently, this study utilised semi-structured interviews, a flexible and insightful qualitative method that allowed us to probe questions and in-depth discussions.

The research is framed as a single case study, focusing on one manufacturing firm as the 'case'. This approach is particularly effective for examining unique phenomena, such as the impact of the COVID-19 pandemic on supply chains. Case studies, as Farquhar (2013) asserts, provide an in-depth understanding of the subject in its natural context and are essential for adding credibility and detail to research findings.

Lastly, this study is characterised as a cross-sectional study, measuring impacts over a short time frame. Saunders et al. (2016) explain that such studies can employ qualitative methods, like the interviews conducted in this research, thereby fitting within the cross-sectional framework. This approach is appropriate for capturing the immediate effects of the COVID-19 pandemic on supply chain disruptions.

3.2. Sampling

For this case study, a non-probability purposive sampling method was chosen as the most appropriate approach, aligning with standard practices in qualitative research. This method involves deliberately selecting individuals who meet specific criteria set by the researcher (Gray, 2009). In this research, the key criterion for participant selection was their managerial role and involvement in the company's supply chain, ensuring the comprehensive coverage of supply chain operations. This selection criterion also ensured that the right individuals with the right knowledge were chosen to participate in the research. The research involved conducting eight interviews with employees from a manufacturing firm engaged in different departments, including producing machinery of air compressors and nitrogen generators, logistics, sales, and support departments. These participants were chosen from different departments to ensure a comprehensive view of the various aspects of the supply chain. The breakdown of the interviewees, according to their department and supply chain involvement, is shown as follows in Table 2.

Table 2. Interview samples.

Department	Description
Logistics and Operations Department	Two interviews were conducted with individuals involved in downstream processes, particularly warehousing finished products.
Business Line Managers	Three interviews were conducted with managers responsible for upstream activities, mainly liaising with suppliers to acquire machines and parts.
Customer Sales/Support Department	Two interviews were conducted with personnel who provided downstream after-sales services and customer support.
Product Specialist	One interview was conducted with a specialist involved in upstream processes, focusing on liaising with suppliers for product launches.

3.3. Data Gathering

In this study, qualitative data collection serves two primary objectives as outlined by Fischer and Guzel (2022): firstly, to understand the breadth of the topic, and secondly, to gain in-depth insights within the topic's context. The initial phase involved conducting a literature review on supply chain disruptions, which provided a broad understanding of the subject. The second phase, aimed at delving deeper into the topic, involved conducting interviews.

The primary method for data collection chosen for this study was semi-structured interviews. This approach was preferred over structured interviews to avoid limiting participants to pre-set questions, thereby allowing for more expansive discussions and exploration of topics raised by the participants. An interview guide guided the semi-structured interviews but was not bound to a strict set of questions, enabling the interviewer to probe further into specific themes or topics for a more profound understanding (Ahlin, 2019). The interview guide comprised open-ended questions to encourage a conversational and interactive flow during the interviews. This guide was structured to address sub-research questions and included the classification questions detailed in Table 3.

Table 3. Research question methodology.

Category	Questions
Role and Responsibilities	"Tell me about your role—what are your day-to-day responsibilities?"
Tenure with Company	"Did you work with the company pre-COVID-19 and/or post-COVID-19?"
Supply Chain Involvement	"Briefly describe your supply chain—in what ways are you involved?"
Demand Fluctuations	"Did demand for products change during the COVID-19 pandemic?"
Logistics Disruption	"Were your logistics disrupted by the COVID-19 pandemic?"
Forecasting Challenges	"Did the COVID-19 pandemic supply chain disruptions impact your ability to forecast customer demand?"
Supplier Lead Times	"Did you experience any change in lead times for goods from your suppliers? Were your suppliers transparent about any change in lead times?"
Impact of Government Lockdowns	"How did Government lockdowns affect your supply chain?"
Disruption Management Strategies	"Did your organisation have the plan to reduce the disruption's effect? If yes, how were contingency decisions made? Individual, team, other?"
Operational Challenges	"What operational challenges have you experienced due to the COVID-19 pandemic supply chain disruptions?"
Strategic Adaptations	"As the COVID-19 pandemic-related disruptions can be seen as 'over' or beginning to be managed, have any decisions been made to adapt a new strategy that prepares the company for future supply chain disruptions?"

To ensure the participants were adequately prepared, they were notified about the interviews a month in advance. This advance notice allowed them sufficient time to review the information sheet and contemplate the questions. The interviews were scheduled throughout March and conducted both via Zoom and on-site at the manufacturing firm to accommodate the preferences and situations of the participants. Zoom interviews were held on the 10th, 24th, and 28th of March 2023, specifically for employees working from home. The other interviews took place on the 23rd of March 2023, at the firm's premises, conducted in a private setting to maintain professionalism and confidentiality. All interviews were audio-recorded using a laptop, enabling the researcher to capture and later transcribe the discussions for analysis accurately.

The interview guide for this study was structured to explore various aspects of how the COVID-19 pandemic has impacted supply chain operations in a manufacturing firm, as shown in Table 3. The guide was divided into classification questions and more specific inquiries tailored to understanding the nature and extent of COVID-19's impact on supply chain dynamics.

3.4. Data Analysis

In this research, a thematic analysis was employed to scrutinise the collected data, a method centred on identifying and analysing themes or patterns within a dataset, as described by Braun and Clarke (2022). Given the inductive nature of this study, themes and codes were derived directly from the interview data. This analysis follows the six-phase process outlined by Braun and Clarke (Nowell et al., 2017), which is designed to ensure the thoroughness and trustworthiness of the analysis.

The six phases are given as follows:

1. Familiarisation with the data: the researcher immerses themselves in the data to deeply understand its content.
2. Generating initial codes: this phase involves creating initial codes from the data encapsulating core concepts or ideas.
3. Searching for themes: from these initial codes, broader themes are identified that represent patterns in the data.
4. Reviewing themes: this phase involves refining the themes and ensuring they accurately represent the dataset.
5. Defining and naming themes: each theme is clearly defined and given a descriptive name.
6. Producing the report: finally, the researcher compiles a report that presents the data and the analysis in a coherent and meaningful way.

Throughout this process, the study focused on initial codes related to the impact of supply chain disruptions on the manufacturing firm, which gradually evolved into key themes reflecting the study's findings. Once the themes were thoroughly identified and reviewed, they were comprehensively reported and can be seen in the findings section of this study, providing a detailed understanding of how supply chain disruptions have impacted the manufacturing firm in question.

3.5. Validity and Reliability

Thematic analysis, the chosen methodology for this study, relies heavily on the researcher's interpretation of data to develop codes and themes. Therefore, ensuring validity and reliability throughout the study is crucial. Validity, as defined by Saunders et al. (2016), refers to the credibility of a study, questioning whether the research findings accurately represent what they claim to be. A meticulous process was followed to ensure the validity of this research. The interview audio and transcripts were thoroughly reviewed multiple times to capture participants' views accurately. In addition, participants were provided with copies of their transcripts to verify that their views were correctly represented. Enhancing the robustness of the analysis, the initial codes identified by the researcher underwent peer review to validate them.

Reliability, on the other hand, concerns the consistency of research findings if the study were to be replicated by another researcher. While it is understood that no two studies will yield identical results, a certain level of consistency is expected. This study addressed reliability through the use of a pilot study. The pilot interview was conducted before the primary interviews to test the reliability of the research questions. It offered an opportunity to refine and potentially add questions to the interview guide, ensuring that

the questions were effectively structured to elicit relevant and comprehensive information from the participants. Through these approaches, this study aimed to uphold a high degree of validity and reliability, reinforcing its findings' trustworthiness and applicability.

3.6. Ethical Considerations

In any research study involving human participants, addressing ethical concerns is paramount. When conducting interviews, it is essential to ensure that participants are not subjected to any form of physical or psychological harm and that they provide informed consent (Gray, 2009). Several measures were implemented to uphold these ethical standards in this study.

Firstly, the ethics form specific to this research was rigorously reviewed and subsequently approved by supervisors, adhering to the guidelines set by Liverpool Hope University. This step was crucial to ensure the study's ethical considerations were thoroughly examined and met the required institutional standards.

In addition, all participants in the study were provided with a detailed research information sheet. This document was designed to inform participants about the nature and scope of the interviews, what their participation would encounter, and any other relevant details about the study. Ensuring that participants are fully informed is crucial to ethical research practice.

Furthermore, to solidify the ethical framework of this study, written consent was obtained from all participants. This process of obtaining informed consent is fundamental in research ethics, as it ensures that participants voluntarily agree to take part in the study with a complete understanding of what it involves.

Lastly, the participants were reassured of the minimal risks involved in their participation. They were informed that the study posed little to no harm to them and that their identities would be kept confidential following the stipulations of the ethics form. Maintaining anonymity and confidentiality is crucial in protecting the privacy and well-being of participants, thereby adhering to the ethical principles guiding the research.

4. Findings and Analysis

This section presents the findings and analysis of the research conducted to understand the impacts of COVID-19 on the supply chain of a manufacturing firm. The analysis draws upon the interview data, aligning with the existing literature on supply chain risks and disruptions. The focus is on both the internal dynamics within the firm and the broader external environment affecting the supply chain. This chapter systematically explores various aspects of supply chain risks and disruptions, from specific challenges faced by the firm to the broader strategic adjustments made in response to the pandemic.

4.1. Internal Supply Chain Risks

The research findings align closely with the existing literature on supply chain risks, particularly highlighting the relevance of Butt's (2021) categorisation of supply chain risks, including forecast risks, stock delivery delays, machine breakdowns, and quality issues in final products. Participants F and G emphasised the challenges faced due to bottlenecks in production and the consequent increase in demand, which lead to uncertainties in forecasting. This situation illustrates the complexities and difficulties in managing supply chain operations during unprecedented events like the COVID-19 pandemic.

Participants C and H further corroborated Butt's (2021) perspective, sharing their experiences with stock delivery delays and quality compromises in products. These challenges reflect supply chain risks' intricate and multifaceted nature, where even minor disruptions can have far-reaching consequences.

This study also reinforced the findings of Manuj and Mentzer (2008), who identified supply, operational, and demand risks as primary factors affecting the supply chain. Additionally, Remko's (2020) insights into the loss of control as a significant supply chain risk were echoed in the participants' experiences. However, a critical finding from the interviews was the heightened external supply chain risks the manufacturing firm faced due to the COVID-19 pandemic. These risks, categorised by Wilding (1998) as demand, environmental, and supply risks, significantly impacted the firm's supply chain operations during the pandemic, underscoring the broader implications of such global crises on supply chain management.

4.2. External Supply Chain Risks

The research findings on external supply chain risks align with established supply chain risks in the literature, shedding light on the specific challenges encountered by a manufacturing firm during the COVID-19 pandemic.

4.2.1. Demand Risks

This study revealed that demand risks, initially seen as potential growth opportunities, quickly became challenges due to COVID-19 pandemic disruptions. Echoing Wagner and Bode's (2008) findings, the initial increase in demand, especially for air compressors in the medical industry, was notable. However, the inability to sustain this demand due to supply chain interruptions led to adverse outcomes, supporting Chang et al. (2015) and Baryannis et al. (2018), who noted that supply chain risks often result in adverse impacts. This was exemplified by the experiences of participants C and G, who faced difficulties when their local stock depleted, leading to increased lead times and an inability to meet customer needs. The firm's supply chain was severely constrained by these demand fluctuations, underscoring the importance of effective logistics management, as Shahbaz et al. (2019) suggested.

4.2.2. Environmental Risks

Participants also highlighted significant environmental risks, which included uncontrollable factors like government lockdowns and border closures. These factors severely impacted the firm's ability to procure necessary materials, as evidenced by participants B, C, and H. Such disruptions in the upstream supply chain network due to environmental risks prevented the firm from acquiring essential stock and machinery, highlighting the broader impact of the COVID-19 pandemic beyond the firm's immediate control.

4.2.3. Supply Risks

Regarding supply risks, the findings resonated with Jüttner's (2005) emphasis on the risks associated with suppliers in the upstream supply chain. The COVID-19 pandemic led to extended lead times from suppliers, significantly affecting the firm's operations. While some departments within the firm experienced effective communication from suppliers, as noted by participants D and H, others, like those mentioned by participants B and F, faced challenges due to a lack of transparency and communication. This variation in experiences underscores the importance of transparent supplier relationships in managing supply chain risks effectively during unprecedented disruptions like a pandemic.

4.3. Supply Chain Disruptions

The research utilised Macdonald and Corsi's (2013) framework to analyse the impact of COVID-19 on the manufacturing firm's supply chain. This framework emphasises the importance of financial performance as a key indicator of overall success. Interestingly, the firm's financial performance was not significantly affected by the COVID-19 pandemic,

as participant F pointed out the consistent demand for their compressed air products, suggesting a degree of resilience in their business model.

However, a critical gap was identified in the firm's preparedness for supply chain disruptions. Participant H's admission of the absence of a pre-existing disruption plan highlights a reactive approach to managing the crisis, which initially impacted their supply chain operations. While not severely affecting their financial performance, this lack of preparedness aligns with the broader trends observed during the pandemic, as noted in Magableh's (2021) study, which reported similar levels of unpreparedness across various industries.

Participant C's comments revealed the specific challenges faced, including delays in shipping and significant increases in transportation costs, consistent with Baghersad and Zobel's (2021) definition of supply chain disruptions, focusing on the interruption in the flow of materials, information, and services.

A recurring theme in these findings was the impact of logistical disruptions, particularly the shortage of drivers, which severely hampered the firm's operations. This finding contributes to Magableh's (2021) study on logistical challenges during the COVID-19 pandemic and highlights the critical role of logistics in supply chain management, as Shahbaz et al. (2019) also emphasised. Participant E's experiences of logistical constraints due to restrictions in Italy further underscore the global nature of the pandemic's impact on supply chains. This global impact is supported by Ivanov's (2020) study, which stresses the significance of the timing of facility operations during lockdowns in determining the overall impact on the supply chain.

In summary, while the manufacturing firm exhibited financial resilience, the lack of a pre-planned strategy for supply chain disruptions led to significant logistical challenges, emphasising the need for comprehensive risk management and preparedness in supply chain operations.

4.4. Supply Chain Strategies

Adapting supply chain strategies in response to disruptions, particularly those induced by the COVID-19 pandemic, was a focus of this research. The findings align with Pujawan and Bah's (2021) recommendation that localising and digitalising the supply chain is crucial for resilience during such unprecedented times. The manufacturing firm's shift towards these strategies was evident in their adoption of an automated ordering system and increased local stock, as participants D and E noted. This approach reduces reliance on international suppliers and enhances the firm's ability to respond rapidly to changes in demand.

These strategic changes resonate with Queiroz et al.'s (2020) study, which emphasises the importance of adoption, digitalisation, preparedness, recovery, and understanding the ripple effect and sustainability of supply chain management. Participant G's insights on reducing the lean nature of the supply chain model to maintain a more extensive stock of raw materials further illustrate the firm's proactive approach to mitigating future disruptions.

The concept of the ripple effect, as experienced by the firm during the pandemic, aligns with the findings of Dolgui and Ivanov (2021b) and Scarpin et al. (2022). Participant F highlighted how each stage of the supply chain was affected, leading to a compounded impact at the end of the chain. This ripple effect underscores the interconnectedness of global supply chains and the need for strategies that can absorb and adapt to such widespread disruptions.

Overall, the impact of the COVID-19 pandemic on the firm's supply chain strategy had a silver lining, as it compelled them to adopt more robust and efficient strategies. These new approaches helped the firm manage the immediate challenges posed by the pandemic and positioned them to better handle future disruptions. This strategic shift

demonstrates the firm's agility and commitment to continuous improvement in its supply chain management practices.

4.5. Impact on Business Operations

The impact of the COVID-19 pandemic on the manufacturing firm's business operations aligns with Vafin's (2021) and Baz and Ruel's (2021) studies on operational risks. The pandemic disrupted the firm's ability to maintain regular operations, as highlighted by participant F, who noted the inability to produce, ship, or invoice finished goods. This disruption severely hampered their capability to serve customers effectively, underlining the profound effect of supply chain disruptions on day-to-day activities.

Despite the overall negative impact, some participants, like participant A, observed that the disruption spurred new business opportunities. These included the development of novel strategies that might not have been considered otherwise. However, the consensus was that negative aspects, such as delayed production and weakened supplier relationships, overshadowed these opportunities. This dual impact of supply chain disruptions reflects the insights of Wagner and Bode's (2008) study, which suggests that supply chain risks can lead to positive and negative outcomes.

A notable finding from the research was the critical role of human resources in the supply chain. Participant A pointed out that even if the supply and delivery processes were uninterrupted, the lack of essential personnel, particularly drivers, posed a significant challenge. This shortage in human resources, especially in logistics, led to substantial disruptions in the supply chain. The study thus sheds light on a less-discussed aspect of supply chain management—the reliance on people, not just processes and materials. This human element of the supply chain is crucial, and its disruption during the COVID-19 pandemic significantly affected the firm's ability to function efficiently.

In summary, while the COVID-19 pandemic led to operational challenges and offered some strategic opportunities, the overall impact on the firm's business operations was predominantly negative. The pandemic underscored the importance of considering human resources as a vital component of the supply chain, highlighting the need for more resilient and people-centric supply chain strategies in the future.

4.6. Main Findings

This study conclusively found that the manufacturing firm faced amplified external supply chain risks during the COVID-19 pandemic. These challenges were primarily due to an unsustainable surge in customer demand, exacerbated by insufficient stock, governmental lockdowns impeding goods movement, and elongated lead times from suppliers. Despite these challenges presenting new opportunities for increased demand and potential sales, the predominant impact of these disruptions was negative. The firm's inability to meet this heightened demand was a direct result of global supply chain delays caused by the pandemic, highlighting a crucial aspect of supply chain management: the vulnerability of logistics to external shocks.

Interestingly, COVID-19 pandemic disruptions also led to some positive developments within the firm. The situation acted as a catalyst for adopting new strategies, such as localising and digitising the supply chain and moving away from an overly lean production model. While borne out of necessity, these strategic shifts have positioned the firm to handle similar disruptions better in the future.

However, the firm's operations were significantly disrupted. The inability to produce and deliver finished goods was a direct consequence of the disrupted supply chain. While these operational challenges did not translate into substantial financial losses, they revealed a critical gap in the firm's preparedness: the absence of a robust supply chain disrup-

tion plan. This lack of preparedness exacerbated the logistical challenges faced during the pandemic.

This study underscores the need for comprehensive disruption plans in supply chain management. Such plans are vital for providing clear guidelines on responding and adapting to sudden and significant disruptions, as evidenced by the COVID-19 pandemic. Implementing a well-structured disruption plan could mitigate the impact of future disruptions, ensuring smoother operations and greater resilience for the firm.

5. Conclusions

The research presented in this study provides theoretical and practical insights into the impact of the COVID-19 pandemic on supply chain disruptions, specifically within the manufacturing industry. Integrating Macdonald and Corsi's (2013) and Magableh's (2021) frameworks offers a novel approach to evaluating such disruptions, making this study a valuable resource for future academic inquiries in the field. This theoretical contribution serves as a foundation for further research, potentially extending beyond the manufacturing sector.

Practically, this study is not just an academic exercise but also a tool of real-world significance, especially for the manufacturing firm involved. The insights gained from the interviews and data analysis can guide the firm in developing more resilient supply chain strategies. The detailed examination of a firm's response to the pandemic-induced disruptions highlights specific areas needing improvement. Providing the firm with a copy of this study and accompanying recommendations emphasises the practical application of this research, offering a template for this firm to strengthen its supply chain resilience.

However, this study has some limitations, primarily the small sample size and its focus on a single firm within the manufacturing industry. While this focused approach allowed for an in-depth examination of the firm's supply chain disruptions, it may have also limited the generalisability of the findings due to the small sample size of participants. Future research could expand this study's scope by exploring other industries to compare and contrast how different sectors have navigated the supply chain disruptions caused by the pandemic. Additionally, including multiple firms within the same industry in future studies could provide a more comprehensive view of the industry-wide impacts of such disruptions. This broader approach could reveal industry-specific patterns and strategies, offering valuable insights into how different sectors adapt to and recover from significant supply chain challenges.

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