Critical significance of supply chain resiliency during and post-pandemic: Analysing the impact of applied supply chain strategies on achieving resilient supply chain in the manufacturing sector

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Dedication

This work is dedicated to my kids (Arnav and Kiaan) and my wife (Priti) whose unconditional love, support, and encouragement have been my constant source of strength throughout this journey. To my parents and brother, for their endless sacrifices and unwavering belief in me, this achievement is as much yours as it is mine. To my friends colleagues and business partners, thank you for your patience, understanding, and for always being there when I needed you the most.

Finally, I dedicate this work to everyone who believes in the power of knowledge and the pursuit of dreams. Thank you all for being a part of my journey, and for helping me to achieve this significant milestone. I couldn't have done it without you, and I am forever grateful for your love and support.

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Finally, I would like to express my heartfelt appreciation to my family and friends for their unwavering support and understanding throughout this journey. Your encouragement and patience have been a source of strength for me.

Thank you all for making this endeavor a success.

ABSTRACT

Critical significance of supply chain resiliency during and post-pandemic: Analysing the impact of applied supply chain strategies on achieving resilient supply chain in the manufacturing sector

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The COVID-19 pandemic underlined the significance of supply chain flexibility, especially in the manufacturing industry, which experienced highly negative impacts from disruptions. This work aims to explore the effectiveness of different supply chain approaches used during and after the pandemic to increase supply chain resilience. To this end, the study extends a wide-ranging literature review to identify how several elements, including digital technology applications, risk management, and supply chain flexibility, have been used to manage disruption and sustain business operations. The study also examines the relationship between resilience and operational performance which encompasses both short-term contingency measures as well as long-term recovery plans in the face of disruptions occasioned by the pandemics. By doing so, the research outlines factors that enhance supply chain resiliency and provides guidance to manufacturing firms that would like to enhance the resiliency of their supply chains to future proof from shocks around the globe. The outcomes proved to be quite helpful in understanding these strategies, and indicated the increasing need for a strategic approach to risk management in supply chain in order to maintain high performance over time, given the current global volatility.

Furthermore, the research aims to analysing the impact of supply chain resilience on operational performance, focusing on long-term configurations for post-pandemic performance and short-term measures in response to disruptions caused by the pandemic. This research provides guidelines that manufacturing firms can use to strengthen their supply chain and prepare for potential future shocks and disruptions by evaluating the effectiveness of the above listed strategies. It also gives an understanding of the main characteristics of supply chain for strength and the essential drivers that foster such strength. The research offers important insights into the suitability of these strategies and underscores the importance of addressing supply chain risks before they materialize and of maintaining superior performance in a world that increasingly poses threats to supply chains.

Keywords: Supply Chain Resilience, COVID-19, Manufacturing Sector, Supply Chain Strategies, Operational Performance, Post-Pandemic Recovery, Digital Technology Integration, Risk Management.

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CHAPTER I: INTRODUCTION

1.1 Introduction

Supply chains are growing more complicated as a result of the rising quantity of global sourcing, which increases the likelihood that they may be disrupted in a variety of ways. Therefore, the ability to recover quickly from, or even prevent, supply chain interruptions is becoming more important (Ribeiro & Barbosa-Povoa, 2018). The present COVID-19 situation has wreaked havoc on supply chains throughout industries, but particularly in manufacturing due to the temporary shutdown of production facilities and the restriction of cross-border transfers. As a result, production had to slow down due to a lack of necessary materials. In addition, businesses don't know how to make their supply chains robust in the face of the COVID-19 pandemic. This is because there is a dearth of information regarding how to mitigate the long-term impacts of COVID-19 on supply chains (Ivanov & Dolgui, 2020b).

So far, the industrial sector has responded in a wide variety of ways to COVID-19-related interruptions in the supply chain. By increasing transparency and providing real-time data on disruptions (Ivanov & Dolgui, 2020a), digital technologies like Industry 4.0 and big data analytics strengthen supply chain resilience. Ivanov et al. (2019) argue that digital technologies have a beneficial effect on demand responsiveness and flexible changes in capacity, both of which have the potential to lessen the severity of the present disruptions. Thus, the COVID-19 situation highlights the need for supply chain agility to be able to swiftly respond and flexibly adjust to changes in the business environment (Blome, Schoenherr, & Rexhausen, 2013). Supply chain agility was recognised by Tukamuhabwa, Stevenson, Busby, and Zorzini (2015).

Supply chain agility includes the ability to quickly and easily make changes to the supply chain in response to changes in demand. Despite its positive effect on supply chain resilience (Juettner & Maklan, 2011), supply chain agility is often implemented only after a disruption has already taken place, according to research by Li, Holsapple, Wu, and Goldsby (2017). Because of the strategic partnership, cooperation, and openness it brings to supply chain operations, supply chain integration is seen as an enabling capacity for proactive supply chain resilience (Altay, Gunasekaran, Dubey, & Childe, 2018). With this level of visibility, problems in the supply chain, like those brought on by the COVID-19 virus, may be identified before they spread. Juettner and Maklan's (2011) research on supply network resilience provides empirical evidence for the causality between supply chain integration and resilience by demonstrating the beneficial effects of cooperation capacities across supply chain participants on supply chain resilience.

As a group, manufacturers care about staying in business for the long haul (Ivanov & Dolgui, 2020b). Therefore, businesses need to create and maintain a competitive edge that allows them to outperform rivals in terms of operational efficiency (Peteraf & Barney, 2003). Delivery and supply and procurement flexibility, on-time delivery, and the conversion flexibility response to urgent deliveries are all recommended indicators by Carvalho, Barroso, Machado, Azevedo, and Cruz-Machado (2012) to evaluate operational performance. As a result, this research measures how operational performance changes as a result of COVID-19 and the use of digital technology in the supply chain.

This chapter provides context for the research, explaining why this issue is significant and highlighting the motivations behind the study. The objectives and questions of this study are also specified.

1.2 Research Problem

Companies nowadays must collaborate with their suppliers and consumers to improve transparency, communication, and efficiency in the supply chain in order to succeed in the global marketplace. Organizations are becoming more cognizant of their operational and economic vulnerability as a result of the complexity of managing global supply chains and meeting customer requirements. Every organizational activity carries the risk of unexpected disturbances that can lead to revenue losses and, in the worst case, firm closures. By developing strategies that allow the supply chain to quickly recover to its original functional state following a disruption, building resilience in the supply chain can help reduce and overcome vulnerability to risks.

The importance of supply chain resilience during and after a pandemic needs to be assessed in the manufacturing sector. Prior studies focused primarily on supply chain resilience during the pandemic and lacked data regarding the post-pandemic environment. Therefore, more emphasis was placed on the supply chain process than on information on supply chain robustness. Studies chosen to complete the literature on the impact of resilient supply chain strategies on the manufacturing industry cannot provide accurate knowledge. Studies place more emphasis on other industries, including hospitality, when it comes to building supply chain resilience as opposed to the manufacturing industry.

1.3 Purpose of the research

In addition, the role of supply chain benchmarking as a potential intervening variable in the connection between SCRE and OP is explored in this study. This is based on previous research by Bhamra, Dani, and Burnard (2011), who noted that many factors affect the relationship between SCRE and OP.

Based on these factors, the research examines the moderating function of supply chain benchmarking in manufacturing enterprises and evaluates the impact of supply chain resilience on operational performance.

The hypothesised connections among the variables, the hypotheses made to evaluate these links, and the interrelationships among the variables Methodology details are provided in the study's third chapter. The study strategy, sample size, and data analysis choices are all examples of these. Data analysis, findings from testing the framework and hypotheses, and discussions of these findings are the focus of Chapter 4. The research questions are also addressed. The concluding chapter, "Chapter Five: Conclusions and Implications for Future Research on Supply Chain Resilience and Operational Performance: The Moderating Role of Supply Chain Benchmarking," summarises the whole work, draws conclusions from the research results, and offers implications of the study and pertinent suggestions for future research in this area.

Next, we define the boundaries of this master's thesis. We educate readers on the worldwide supply chain disruption brought on by COVID-19 and its effects on the manufacturing industry. We discuss the scope and constraints of this research and identify the issue based on these obstacles.

In December of 2019, researchers in Wuhan, China, identified the Coronavirus that would later be named COVID-19 (WHO, 2021). By the time we finished our study (Johns Hopkins University, 2021), it had caused a global pandemic, with an estimated 167 million cases of illness and 3.5

million fatalities. COVID-19 not only has far-reaching effects on the world's healthcare system, but it has also highlighted the manufacturing industry's and its supply chains' susceptibility to risks and disruptions (CIPS, 2020; van Hoek, 2020). The main global automakers rely on Wuhan as a key centre of car component production for essential components (LMC, 2020). This has led to concerns that the COVID-19 epidemic might spread to the auto industry. As a result, manufacturing halted across the world when Wuhan was declared a quarantine zone in February 2020 (Hofstätter et al., 2020), despite the fact that the virus had not yet travelled to Europe or the United States. Due to their placement in quarantine zones in China, South Korea, and Italy, up to 3,500 automotive and industrial facilities were inaccessible in March 2020.

The worldwide passenger vehicle market declined by 17% in 2020 compared to the previous year, but the industry was able to stabilise its supply chains by the end of the year. On the other hand, January 2021's chip shortage demonstrated that the disturbance is still producing fallout throughout the supply chain. In the near term, the automakers' present chip supply capacity could not meet the unexpectedly strong consumer demand recovery, therefore manufacturing was halted.

In sum, the COVID-19 disruption will have lasting effects on the car industry's supply networks. McKinsey and the Boston Consulting Group put the time frame at two years.

Until at least 2020 (Hofstätter et al., 2020) for the world's automotive sector to recover from the pandemic's disruption. However, even before the COVID-19 outbreak, the manufacturing sector was facing enormous difficulties, including electric mobility, autonomous vehicles, smart factories, and ridesharing (Hofstätter et al., 2020). The manufacturing industry's prominence in the global economy makes its supply networks of particular relevance. In addition, previous supply chain research and literature (Womack et al., 1990) relied heavily on the manufacturing sector. Consequently, there are a number of arguments in favor of looking into the automotive supply chains, especially in light of the tremendous disruption caused by the COVID-19 virus.

1.4 Significance of the study

When it comes to connecting the dots between raw materials and finished goods, supply chains are important. Most academics are increasingly interested in studying sustainable supply chain management (SSCM) for both qualitative and quantitative reasons. The research highlights the importance of supply chain resilience and its bearing on the operational success of businesses. This will aid both practitioners and academics in figuring out how to minimise the worldwide impact of supply chain disruptions. Absorbent capacity is shown to have an interactive influence on the aforementioned relationship. This will reveal potential new capabilities that businesses may develop to strengthen their resistance to disruptions and provide them with an advantage in the market. New supply chain resilience techniques that have been implemented or uncovered are also analysed. Growing businesses may gain an edge over rivals if their supply chains are managed efficiently and resiliently in the face of upheaval. As a result of this research, policymakers and supply chain managers will be better equipped to implement and adopt supply chain resilience practises that will enhance supply chain and business performance while ensuring economic and social sustainability, ultimately contributing to development. Finally, the study contributes to existing information and serves as a reference for researchers engaged in related endeavours.

The research aimed to understand the impact of supply chain resilience on supply chain performance, with an emphasis on the moderating role of supply chain benchmarking in this connection. Supply chain resilience was operationalized in this research with the use of a variety of variables, including teamwork, sturdiness, knowledge, public-private partnerships, technological prowess, adaptability, and risk management. Resources, output, responsiveness to customers, and cost performance (including inventory cost, operating cost, and lead time) were used to define Operational Performance. In addition, "delivery performance, flexibility, cost, and quality)" were used as indicators of supply chain benchmarking.

- Nonetheless, this research focuses on the manufacturing sector.
- The overarching goal of this research is to analyse the moderating effect of supply chain benchmarking on resilience and operational performance at manufacturing enterprises. The following are the precise aims of the research:
- The goal of this study is to analyse the impact of supply chain resilience on the productivity of factories.

Objective: Determine the impact of supply chain benchmarking on business results. To assess the moderating effect of supply chain benchmarking on the relationship between supply chain resilience and operational performance.

What Are We Looking For?

- The following questions were addressed in order to achieve the study's goals:
- How does the robustness of businesses' supply chains affect their productivity?
- How does benchmarking the supply chain affect the efficiency of operations?
- When considering the connection between supply chain resilience and operational effectiveness, what role does supply chain benchmarking play?

1.5 Research purpose and Questions

This study will analyse and evaluate the SCRE related to the COVID-19 disruption with input from the manufacturing sector. In this research, we examine three elements of SCREs in the manufacturing sector via the lens of a qualitative multiple case study based on interviews with specialists in the supply chain from the manufacturing industry. The objectives of the study are as follows:

- R01 To examine the significance of supply chain resiliency in the manufacturing sector at the time of covid-19
- R02 To evaluate the importance of supply chain resiliency after the covid-19 in the manufacturing sector
- R03 To analyse the impact of strategies related to supply chain applied for achieving resilience in the supply chain during the pandemic within the manufacturing sector
- R04 To scrutinize the impact of strategies linked with the supply chain applied for meeting resiliency in the supply chain post-pandemic within the manufacturing sector

Many studies have been conducted on the topics of supply chain resilience, supply chain agility, and supply chain integration. point out that there is a dearth of research on the effects of digital technologies on supply chain resilience and its capacities and consequences.

This study aims to fill this knowledge gap by exploring the potential and repercussions of supply chain resilience when digital technologies are applied to the manufacturing sector. Thus, the quantitative effects of studying supply chain resilience, agility, and integration as capabilities and operational performance as a result of supply chain resilience are all investigated in the same context. The results should shed light on how digital technology might act as a moderator in the context of supply chain resilience, as well as its relevance, capabilities, and repercussions. Therefore, the following research issues will be addressed in this study:

- RQ1 What is the significance of supply chain resiliency during the pandemic in the manufacturing sector?
- RQ2 What is the importance of supply chain resiliency after the pandemic in the manufacturing sector?
- RQ3 What is the impact of supply chain strategies applied for achieving resilience in the supply chain during the pandemic within the manufacturing sector?
- RQ4 What is the impact of supply chain strategies applied for achieving resilience in the supply chain post-pandemic within the manufacturing sector?

CHAPTER II: REVIEW OF LITERATURE

2.1 Supply Chain Management and Resilience Studies

The supply chain resilience field has generated a large body of literature that spans several disciplines. After devastating events like 9/11 and the Thai tsunami, researchers were keenly interested in the topic of supply chain resilience (Christopher and Peck, 2004; Rice and Caniato, 2003; Sheffi and Rice, 2005). It is not unexpected that the resilience of supply networks is being more discussed in scholarly literature in the wake of disasters like Hurricane Katrina and the nuclear disaster at Fukushima. These changes demonstrate, according to Hohenstein et al. (2015), that resilience research will likely be stepped up in the next years, since supply chain resilience demonstrated to be a significant component for organizations' competitiveness.

Much of this research is concerned with defining resilience, elaborating on its significance, and identifying the elements and traits that contribute to the robustness of a supply chain or business (Ponomarov, 2012). Sheffi and Rice (2005), authors of one of the first articles on SC-Resilience, laid the groundwork for future studies of resilience by identifying the characteristics shared by businesses and supply chains that fared well during disruptions. The authors developed a disruption profile that permits classifying each disturbance into one of eight levels. Moreover, Sheffi and Rice (2005) discovered that redundancy and flexibility boost SC-Resilience, with the most significant step that businesses can take to fundamentally and effectively boost their resilience being to enhance their flexibility. Hendricks and Singhal (2005) add to our knowledge of supply chain disruptions by studying the onset, duration, and potential for rapid reversal of aberrant stock price behavior due to disturbances. This article analyzes the consequences of supply chain interruptions on a company's long-term stock price and equity risks. The authors looked at the connection between declared interruptions and stock price performance using empirical research based on a sample of 827 disruptions notified by firms from 1989 to 2000. They found that regardless of the root cause of disruptions, all industries were negatively impacted by them, and the average abnormal stock returns of firms that experienced disruptions were about 40% lower than the stock returns of benchmark companies.

A few of years later, in 2009, Hendricks, Singhal, and Zhang investigated how operational slack, diversification, and vertical relatedness affected the stock market's response to SC shocks. The findings are based on an examination of 307 SC disruptions reported between 1987 and 1998. Stock market reactions appear to have little to do with the breadth of a company's diversification, and companies that deal with more operational gaps in their SC tend to have a positive experience. A high degree of vertical relatedness is associated with a less unfavorable response than geographically diverse experience does in organizations. Atypical returns may be assessed using one of two approaches, including the market model and the portfolio matching model provide very comparable results, proving that supply chain disruptions have a detrimental impact on the stock market.

Ponomarov and Holcomb (2009) take a more theoretical approach to the issue of resilience, undertaking a thorough literature survey across several disciplines and dimensions in order to provide an integrated viewpoint and a conceptual framework of resilience. Their studies fill in some of the theoretical blanks in the current literature and help us better grasp the idea of resilience. After developing a theoretical foundation for resilience, they concluded that there is a lack of knowledge of the core components of supply chain resilience, as well as the linkages between these components and the strategies used to manage them. Leat and Revoredo-Giha's (2013) article examines a case study of the ASDA PorkLink agri-food supply chain in Scotland to discuss risk and resilience in supply chain research. With a primary emphasis on the supply of a key commodity and its inherent difficulties, this article aimed to identify and categorize the various risks involved in creating and sustaining a resilient agri-food SC. The article indicates that both horizontal and vertical collaboration lead to decreased SC-vulnerability, while risk management and stakeholder cooperation lead to greater SC-resilience. In a cross-sectional study of German businesses, Wagner and Bode (2006) go further into supply chain hazards and evaluate the connection between supply chain vulnerability and supply chain risk. The effect of three types of supply chain disruptions on performance was analyzed, along with the link between several supply chain features thought to promote SC-vulnerability. Researchers found that SC-characteristics including reliance on select clients and suppliers, levels of single sourcing, and participation in global sourcing programs all increase a company's vulnerability to supply chain risks. Therefore, the article provides justification for organizations and supply chain configurations to seek an acceptable risk-benefit trade-off.

The identification and suggestion of ways for adopting robust measures in supply networks is another focus of studies within the field of supply chain risk management and resilience. Among the first works on the subject is a paper by As in, "Christopher and Peck" (2004). The article recommends ways to strengthen supply networks generally and focuses on the creation of a managerial agenda for risk assessment and management in the supply chain. The paper's suggestions could help businesses better classify risks and build robust SC-measures. Using a survey and case study methodology, Christopher & Peck (2004) identify cooperation, agility, and the development of a risk management culture as crucial enabling factors for SC-resilience. In contrast to the earlier paper, Tang (2006) used a literature review and case study methodology to identify various measures that assisted businesses in bolstering the robustness of their supply chain, and then proceeded to propose a set of nine strategies, such as postponement, strategic stock, or a flexible supply base, that are capable of doing so. When disruptions occur, using one or more of these techniques promotes resilience. However, firms still need to minimize their risk exposure, as stated by Tang (2006).

Thirdly, researchers in the subject of resilience are trying to determine how various interventions influence supply chain resilience. In order to examine the connections between agile and resilient strategies and SC performance and competitiveness, Carvalho, Azevedo, and Cruz-Machado (2012) created a conceptual framework. The operational performance of a supply chain is evaluated in terms of its adaptability and responsiveness, and the economic performance is measured in terms of the costs associated with inventory and resource redundancies for the purpose of the conceptual framework. This study compares two approaches to supply chain management and demonstrates that although the agile method strives for a quicker reaction to shifting markets and consumer demands, the resilient method is better equipped to weather disruptions and maintain supply chain competitiveness.

Conducted an evaluation of potential scenarios for bolstering the supply chain's resilience and robustness in order to learn how different mitigation measures influence the performance of various chains. Supply chain resilience was redesigned by Carvalho et al. (2011) using simulation. As a consequence, 6 different scenarios were developed to show the SC before and after a disturbance, both with and without redundancy and flexibility. Total cost and the lead-time ratio (the difference between the actual and projected lead-time) were used to evaluate performance. The authors found that although both approaches helped mitigate the negative impacts of disruptions on supply chain performance, flexibility techniques ended up costing less overall. do the same thing for supply chain performance, simulating and comparing it under varied conditions of unpredictability and information sharing. Both a proactive and reactive supply chain are analyzed for the simulation, with the latter to be run under both high and low demand. Customer service, inventory performance by supply chain stage, and overall system inventory are the supply chain variables to be compared. According to the simulation results, a response-based supply chain may outperform an anticipatory one by providing better customer service and maintaining smaller stocks in the face of reduced demand uncertainty. Qiang and Nagurney (2009) built a model of the supply chain that considers both the risks on the demand and supply sides. In this model, the supply risks were unknown, and the demand was made to be random. The model is an extension of existing models that include several transit methods from producers through retailers and finally to the demand markets.

A weighted SC performance and resilience metric, based on the derived network performance, is also proposed as a result of the research. In an empirical analysis of the German car industry, Thun and Hoenig (2011) examine the significance of various hazards in terms of their occurrence likelihood and possible effect on the supply chain. Compared to external supply chain risks, internal supply chain risks are seen as more likely to arise and would have a higher effect on the SC. In addition, the findings demonstrate that the average value for disruption resilience is highest when supply chain risk management is reactive, while the values for flexibility and safety stocks are highest when supply chain risk management is proactive. Companies with a low degree of SC-Risk management instrument application have lower typical values across the board for all performance metrics studied. Recent research by Soni and Jain To make it easier to compare various supply networks, & Kumar (2014) create a unified metric for assessing supply chain resilience. The supply chain resilience index (SCRI) encourages the incorporation of resilience features in supply chain architecture by combining numerous criteria into a single metric. In addition, it provides a decision support tool for assessing and incorporating resilience into supply chain management by allowing practitioners and academics to better compare and analyze the resilience of supply networks and various firms.

Although a wealth of information is available on the topic of resilience, the vast majority of published research has focused on either defining the concept of resilience (Sheffi and Rice, 2005) or emphasizing its importance or identifying certain characteristics, which have influence on the resilience of a supply chain (Thun and Hoenig, 2011). Most of these studies, however, look at individual elements that contribute to SC-Resilience in a vacuum, without considering their interconnection. Therefore, there is currently a paucity of knowledge about the most crucial aspects of supply chain resilience and their interconnections (Wieland and Wallenburg, 2013). Furthermore, few articles exist that focus on identifying and analyzing antecedents and linking those skills to the outcomes of resilience (Carvalho et al., 2011). Ponomarov (2012) argues that there is a dearth of theoretical rationale for existing frameworks of robust supply chains, and that most studies aimed at providing a more in-depth knowledge of the resilience domain are still qualitative. Some obvious holes exist, such as the need for quantitative testing of proposed conceptual models and the failure to conceptualize the complex cause-effect relationships between the various characteristics that foster resilience and the analysis between antecedents and consequences of supply chain resilience (Ponomarov, 2012; Wieland and Wallenburg, 2013).

A small number of publications have appeared in recent years that attempt to define resilience in supply chain management and provide empirical testing of the assumptions based on structural equation modeling.

Logistics and supply chain competences and capabilities, as well as the impact of resilience on supply chain customer value, are the focus of research by Wieland and Wallenburg (2013). They identify the difference between proactive and reactive resilience and conduct empirical research on the impact that collaboration, coordination, and sharing have on responsiveness and toughness. It was discovered by Wieland and Wallenburg (2013) that whereas integration had no impact on either component of resilience, communication and collaboration had a favorable affect on agility. They also concluded that a supply chain's customer value is increased when it is more resilient, which is enabled by investments in agility and robustness.

To better comprehend and assess management of business risks connected with supply chains surveyed 50 French firms. The authors looked at how a business's risk outlook, SC-Risk Management tools, and risk mitigation strategies all play a role in its overall resilience and risk management along the supply chain. According to the report, supply chain risk management should be seen as a cross-organizational management role with strong ties to the everyday realities of business. Collaboration and the formation of collaborative and cross-company procedures are important precursors to a successful risk management encouraging resilience. The relationship between the antecedents of resilience and their influence on supply chain performance at the firm level was also explored by Ponomarov (2012), who also constructed a conceptual model of supply chain resilience. He paid specific attention to the way in which certain skills affect the robustness and efficiency of a supply chain as a whole, and he also included moderating elements into the overarching framework. Ponomarov (2012) demonstrated that SC-Capabilities and the ability to share knowledge positively impact SC-Resilience, which in turn positively impacts SC-Performance. Despite extensive research, this report was unable to establish a connection between supply chain risk management and resilience. Therefore, the model suggests and proves the essential interrelationships between capabilities, resilience, and performance, but failing to include risk management strategies and other skills that might affect SC-Resilience.

Ponomarov (2012), Wieland and Wallenburg (2013), Carvalho et al. (2012), and Lavastre, Gunasekaran, Spalanzani (2012) all provided foundational conceptual frameworks that this research expands upon. Although this paper's model is built on the research of the aforementioned scholars, it improves upon their work by integrating their distinct methods and results to provide a more complete and comprehensive framework for thinking about SC resilience. Extension of Ponomarov's (2012) paradigm via the incorporation of two components, Supply Chain Strategies and Risk Management Capabilities, is what makes this thesis unique. In addition, no moderating impact on resilience was found in the literature, hence no moderating factors or variables were included in the conceptual model. Since Wieland and Wallenburg (2013) only studied the impact of integration, collaboration, and communication on agility and robustness, the categorization of resilience into these two dimensions is another novel aspect of resilience research. Finally, the thesis looked at the resilience field in a new kind of company setting. While most prior research has concentrated on corporations in wealthy nations like Germany and the United States, this thesis focuses in on businesses in Thailand, a nation with a more precarious economic and political character.

2.2 Resilient Supply Chains

Given that resilience is still a relatively new area of study in the SCM, there is no universally acknowledged or widely used definition for this complex concept. From the first efforts to define resilience in SCM, derived their own, more organizationally focused definition. They explain that SCM resilience is the "ability to react to an unexpected disruption, such as one caused by a terrorist attack or a natural disaster, and restore normal operations." However, resilience is defined differently. According to these authors, resilience is the capacity of a system to endure external shocks and rapidly recover to its original condition or even improve upon it. Ponomarov and Holcomb (2009), using a cross-disciplinary strategy, have created the perhaps most comprehensive and theoretically grounded definition of resilience to date. In their definition of supply chain resilience, Ponomarov and Holcomb (2009, p. 131) state that it is "the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function."

According to the research conducted by Hohenstein et al. (2015), who conducted a comprehensive literature review on the topic of supply chain resilience, many researchers have proposed their own definitions of supply chain resilience, but these definitions are merely slight modifications or combinations of previous definitions (Jüttner and Maklan, 2011; Ponis and Koronis, 2012; Wieland, 2013) or relate to other authors (Blackhurst, Kaitlin, and Craighead, 2011; Golgeci and

Po This research agrees with Ponomarov and Holcomb's (2009, p. 131) definition of resilience as the "capacity to prepare for unexpected events, respond to disruptions, and recover from them," and that's what we'll focus on here. Christopher and Peck (2004) highlight a fourth step of improvement (reaching a more preferable condition following disruption) based on these three phases of preparation, response, and recovery. Most studies on supply chain resilience highlight the need of distinguishing between these two phases: the first, reaction and recovery, may be thought of as the reactive dimension, while the second, preparedness and improvement or development, can be thought of as the proactive dimension.

According to Wieland and Wallenburg (2013), the authors of this research refer to these two aspects of resilience—the proactive and reactive—as agility and robustness, respectively. Fernie, Sparks, and McKinnon (2010) define agility as a concept characterized by an obligatory information enrichment consultative forecast mechanism in order to respond rapidly to changing requirements or scenarios. Christopher and Peck (2004) and Blackhurst, Kaitlin, and Craighead (2011) identify visibility (e.g., communication, information sharing) and velocity in achieving responsiveness and recovery as crucial components of agility.

In contrast, robustness is "the ability of a supply chain to resist change without adapting its initial stable configuration" (Wieland and Wallenburg, 2012, p. 890) and is characterized as the proactive feature of resilience (Shukla, Lalit, and Venkatasubramanian, 2011). In addition, supply chain resilience allows operations to continue even when interruptions occur (Meepetchdee and Shah, 2007) and aids in keeping performance at a high level regardless of the circumstances (Harrison, 2005).

2.3 Supply Chain Focus

Companies are increasingly adopting cooperative organizational structures in order to adequately account for the rising complexity and unpredictability in today's corporate environment and to enhance efficiency and effectiveness (Achrol and Louis, 1988; Stank, Davis, and Fugate, 2005). The resource dependence hypothesis (Fynes, Burca, & Marshall, 2004) states that in times of uncertainty, businesses might better use resources by skimming off what they need from their supply chain partners. Establishing governance measures and reducing uncertainty across a supply chain may include developing deeper, durable collaborations, such as with lead suppliers. This highlights the growing importance of a strategic supply chain focus (Ponomarov, 2012). But you shouldn't call it a Supply Chain if you don't want to.

Supply Chain Management and Orientation are synonyms. Firms with a SC perspective, according to Mentzer et al. (2001), can "detect and properly assess which systematic, strategic impact and scope tactical activities have" in order to manage the supply chain's various flows of materials, data, and cash. Therefore, a SC-Oriented company is aware of and prepared to deal with the size and significance of regulating and managing product, service, financial, and information flows throughout their upstream and downstream supply chain. Furthermore, Supply Chain Orientation is seen as a management philosophy defined by the cultural norms and practices of the firm to cultivate the essential abilities with the end goal of establishing competitive advantages at both the tactical and strategic levels (Mello and Stank, 2005). Trust, dedication, collaboration, organizational compatibility, and support from upper management are all components of the SC-Orientation that contribute to its success (Ponomarov, 2012).

H1b: A focus on the supply chain may improve agility.

H2b.Robustness improves with a supply chain orientation

2.4 Strategic Planning for the Supply Chain

It is crucial for businesses to have the ability to foresee and respond to potential disruptions in the future, say Yang et al. (2009). The members of a SC must be able to proactively anticipate different scenarios and implement reliable solutions and strategies that prevent their supply chains from suffering the negative effects in the future in order to reduce risk and disruption vulnerability by a robust set-up. For this reason, resilient supply chains need both foresight and preparedness, as well as initiatives that cultivate these traits (Wieland and Wallenburg, 2013). By building in safeguards and allowing for more maneuverability, businesses can lessen the severity and frequency of supply chain interruptions. Safety stocks, supplementary inventory, different sourcing, back-up facilities, and other redundancy-based strategies are all examples of ways to increase a system's resilience.

Though they increase overhead, redundancy solutions enhance resilience and lower total supply chain risk (Tang, 2008), as noted by Sheffi and Rice (2005). To lessen the possibility and effect of disruptions, Christopher and Peck (2004) believe that companies should choose supply chain methods that keep numerous choices open, even if this means spending more money in the near term than they would on more lean and efficient techniques.

H1c: Agility is enhanced by using supply chain management strategies.

H2c.:Robustness is enhanced by using supply chain management strategies

2.5 Resilience in Supply Chain Operations and Efficiency

According to this research's definition of supply chain resilience, the operational performance of the supply chain is restored as soon as possible following a disruption, if not better than before (Tukamuhabwa B., Stevenson, Busby, & Zorzini, 2015). In addition, supply chain resilience is meant to mitigate the ill effects of a disruption in the supply chain, which would otherwise lead to capacity shortages and delivery delays (Tukamuhabwa B., Stevenson, Busby, & Zorzini, 2015). Supply chain resilience, which involves being ready to counteract a disruption with proactive and reactive resilience capabilities (Behaldi, et al., 2021), is expected to have a positive effect on operational performance in terms of ensuring a certain service level and on-time delivery.

Supply chain integration as a proactive resilience capability and supply chain agility as a reactive resilience capability were shown to have a direct impact on operational performance, for example by ensuring on-time delivery or short lead-times in general (Prajogo & Olhager, 2012; Eckstein, Goellner, Blome, & Henke, 2015; Shin H., Lee, Kim, & Rhim, 2015; Blome, Schoenherr, & Rexhausen, 2013).

In addition, supply chain integration between different suppliers (Pettit, Fiksel, & Croxton, 2010) and supply chain agility (Juettner & Maklan, 2011) are hypothesized to positively influence supply chain resilience. Therefore, it is reasonable to anticipate that supply chain resilience will favorably affect operational performance by averting interruptions or at least mitigating their effect (Tukamuhabwa, Stevenson, & Busby, 2017). In this way, supply chain resilience, which is defined by the ability and the know-how to realign the supply chain (Um & Han, 2021), leads to better operational performance due to the capacity to respond to shifts in market demand. Based on these results, we may propose the following theory:

The operational performance is favourably impacted by a resilient supply chain (H3).

The Mediating Role of Digital Technologies in Supply Chain Integration and Resilience

Supply chain operations such as forecasting, warehousing, distribution, and information transmission along the supply chain can all be realized more effectively with the help of digital technologies (Wiengarten, Pagell, Ahmed, & Gimenez, 2014; Wang, Lin, Xie, & Zhang, 2020). Joint value creation resulting from the merged competences of the involved supply chain partners is expected to facilitate coping with supply chain disruptions and ensure a resilient functioning because supply chain integration involves the sharing of information between partners, for example, regarding demand forecasting and changing requirements (Wiengarten, Pagell, Ahmed, & Gimenez, 2014). By cooperatively managing disruption risks and their available resources to mitigate disruptions, supply chain resilience may be improved thanks to one component of supply chain integration: the quality of integration between the partners. By then, digital technologies are expected to facilitate and strengthen the impact that an integrated supply chain has towards supply chain resilience, through collaboration (Wiengarten, Pagell, Ahmed, & Gimenez, 2014) as well as the sharing of information and competences between partners (Ju & Hou, 2021). As a result, digital technologies like Clouds aid in the convergence of supply chain partners' operations, allowing for a comprehensive identification of supply chain hazards, which should increase the supply chain's resilience (Arrais-Castro et al., 2018). Digital technologies, such as Big Data or tracking and tracing technologies, further support the capability of supply chains to be prepared for disruptions, for instance through synchronized capacity plans of supply chain partners that are adapted to the demand (Ivanov, Dolgui, & Sokolov, 2019) based on the integrated supply chains that are supposed to proactively render supply chains more resilient. Since digital technologies are more transparent and accurate, they may give data-driven decision support for the supply chain network about countermeasures and possible tactics (Ivanov & Dolgui, 2020b). Partners in integrated supply chains may take these digitally created suggestions into account when making adjustments to their supply chain operations (Zhu, Krikke, & Caniels, 2018; Ralston & Blackhurst, 2020). Based on these results, we may propose the following theory:

Supply chain integration and resilience are related, however digital technologies attenuate this link.

2.6 Efficiency in Operations

Operational performance is defined as the extent to which a corporation responds more quickly than its rivals to changes in the business environment. As a result, Shin H., Lee, Kim, and Rhim (2015) use the term "responsiveness" to describe operational performance. The organization has to develop and establish specific goals, such as those related to product quality in order to achieve a high level of operational performance. Improvements in product quality, delivery time, and customer service are all aspects of an organization's operational performance. Flexible production across goods, production volume, and production costs are all mentioned by Prajogo & Olhager (2012) as aspects of operational success. The operational performance of a business benefits from both reliability and innovation (Geyi, Yusuf, Menhat, & Abubakar, 2020).

In addition, expanding into new areas and launching innovative goods or services may boost a business' bottom line. The impact on operational performance may be determined by analyzing these factors separately. According to the research of Chahal, Gupta, Bhan, and Cheng (2020), operational performance is often used as a synonym for competitive advantage when a business excels in one of the operational performance components thanks to a strategic resource.

2.7 Creation of Hypotheses

Previous studies have looked at the relationship between operational performance, digital technology, and supply chain resilience. Hypotheses are developed in the following paragraphs based on the possible connections between the components.

2.8 Informational Tools

Digital technologies have been popularized by the widespread usage of many internet-connected devices at the same time (Ghobakhloo, 2019). Connectivity, integration, and automation inside of business operations are made possible by digital technologies (Ivanov, Dolgui, & Sokolov, 2019; Li, Dai, & Cui, 2020). Examples of digital technologies include Cyber-Physical-Systems (CPS), the Internet of Things (IoT), Big Data Analytics (BDA), and Cloud Computing. Using digital technology, businesses may systematically evaluate data collected throughout the course of the whole product lifecycle, from initial concept to final sale (Tao, Qi, Liu, & Kusiak, 2018).

This data includes process parameters and product qualities. Because of this, new business models have emerged with the development of these digital technologies, which threaten the status quo of traditional factories while also opening up exciting prospects for value addition in the sector (Ardolino, Saccani, Adrodegari, & Perona, 2020). These digital technologies are sometimes referred to as "enabling technologies" (Li, Dai, & Cui, 2020) for I4.0. The term "Industry 4.0" (or "I4.0") is used to describe "smart factories," in which digital technologies are integrated in a complementary fashion into the production system's underlying architecture (Zheng, Ardolino, Bacchetti, & Perona, 2020), with the goal of achieving interoperability that enables systems to interact fluidly regardless of the hardware or software in use (olakovi & Hadiali, 2018). Technically speaking, digital technologies enable the vertical and horizontal integration of production networks. based on constant two-way communication of data and adaptable manufacturing procedures, allowing for individualized product creation (Jabbour, Foropon, & Filho, 2018).

The improved information processing capabilities of digital technology provide up new opportunities for supply chain managers to reimagine the layout of their operations. According to Shou, Li, Park, and Kang (2017), manufacturing companies may improve the quality and quantity of information flows from the supply of raw materials to the delivery of finished products by using digital technology in their supply chain activities. Decision support is provided for demand forecasting, pricing, and product development to better meet customer demand thanks to the transparency afforded by digital technologies in the supply chain (Joshi & Gupta, 2019; Kagermann, Helbig, Hellinger, & Wahlster, 2013). Manufacturers, for instance, can speed up the process of changing assembly lines and managing inventory in response to changes in orders and production failures thanks to real-time data interchange with supply chain partners (Raji, Shevtshenko, Rossi, & Strozzi, 2020). That not only shortens the time it takes to get items from one place to another in the supply chain Aligning company-wide procedures (Arrais-Castro, et al., 2018) not only strengthens supplier integration (Frank, 2018), but also improves supplier-company collaboration.

Despite the many good effects discovered for digital technologies, its full potential has not yet been realized. Only a minority of the current manufacturing systems are highly networked. Most of the problems stem from the application's complexity in a production environment (Nudurupati, Tebboune, & Hardman, 2016; Warner & Wäger, 2019). Partners in a supply chain might vary greatly in their data management capacities depending on their degree of digital maturity (Wu, Cegielski, Hazen, & Hall, 2013). Tyagi, Darwish, and Khan (2014) found that many companies' computing infrastructure is unsuitable for effectively processing the data provided by digital technologies. For example, this is because of the focal company's and the suppliers' inability to resolve technical differences over IoT standards and interfaces (Fatorachian & Kazemi, 2018). Since IoT gathers information from a wide range of production system touchpoints, it must be organized into a decision-making support system that then processes, analyses, and makes available the relevant information to supply chain participants. As a means of addressing this difficulty, agreements

There has to be consensus between supply chain partners on how to handle such IoT data (Brousell, Moad, & Tate, 2014).

2.9 Capabilities of Information Systems

In order to be highly agile and resilient, a business requires both insight to better identify future changes and speed to be able to react swiftly to such changes (Christopher and Peck, 2004). Therefore, gaining this transparency is crucial to giving businesses the ability to spot and appropriately react to shifts in the market. According to Barratt and Oke (2007), investments in information management skills may improve transparency. Managers' ability to spot and react quickly to change or disruption may be improved by the dissemination of relevant data (Holweg and Pil, 2008; Wieland and Wallenburg, 2013).

Exchanging Data may be defined as "the degree to which vital and confidential data are shared with supply chain partners. Communication between businesses is essential for the effective management of networked risks, especially in the context of increasingly complex and worldwide supply chains (Wieland and Wallenburg, 2013). Internal and external risks may be mitigated by open communication between enterprises in a supply chain (Hallikas et al., 2004). A more robust supply chain is the result of open communication between enterprises on demand, supply, inventory, and production schedules (Christopher and Peck, 2004). Durach, Wieland, and Machuca (2015) state that a high level of communication and cooperation among all participants in the supply chain is crucial to achieving resilience. According to Lavastre et al. (2012), supply chains are becoming more resilient and able to avoid risk as a consequence of initiatives to increase transparency in the supply chain via the sharing of risk-related information.

H1a : Agility is enhanced by the capabilities of information systems

H1b : Robustness is enhanced by the capacities of information systems

2.10 Theoretical Framework

While resources define a company's competitive advantage (Wernerfelt, 1984), capabilities go further by combining and using these resources to realize benefits which is where the dynamic capability theory originates from (Blome, 2013). According to the authors of the dynamic capabilities hypothesis (Teece, Pisano, and Shuen, 1997), a company's ability to adapt to new circumstances and opportunities is a reflection of its dynamic capabilities. Thus, dynamic capacities suggest the firm's ability for innovation, openness to change, and the realization of improvements that benefit the firm's consumers at the expense of its rivals (Teece, Peteraf, & Leih, 2016). In order to become or keep being competitive, businesses must use a process of deploying dynamic capabilities known as detecting, seizing, and transforming the dangers and opportunities of the evolving business environment (Teece D., 2007). As a result, consistent and long-term deployment of flexible capabilities that support the business's overall strategy is crucial. Companies with particularly high dynamic capacities are better able to foresee emerging innovations (Teece, Peteraf, & Leih, 2016). Wilden & Gudergan (2015) caution against over-sensing in a stable economic environment, since doing so may result in excessively high expenses that are not warranted by the comparatively modest returns arising from the incorporation of dynamic capabilities.

This research applies the notion of dynamic capabilities to the field of supply chain management by using statistical methods to examine the bond between supply chain agility and integration, the latter of which stands for the dynamic capabilities of supply chain resilience. As a result, supply chain resilience is a flexible capacity that improves productivity. Companies with strong dynamic capabilities combine, on the one hand, a capable leadership team with, on the other, a solid and dependable business framework (Teece, Peteraf, & Leih, 2016).

A source of chains, resilience is a capacity that can adapt to novel circumstances and new information in real time (Yu, Jacobs, Chavez, & Yang, 2019). Therefore, agility as a dynamic capability within the supply chain was discovered to be directly beneficial for the operational performance (Teece D., 2014), particularly for global operations, in terms of flexibly delivering the correct product at the predefined quality, quantity, and time (Blome, Schoenherr, & Rexhausen, 2013). Consequently, the ability to respond rapidly to and adapt to changes in the business environment is a significant competitive advantage (Blome, Schoenherr, & Rexhausen, 2013). The use of cutting-edge information and communication technology is boosted by the dynamic capacity of agility, which speeds up processes like implementation (Warner & Wäger, 2019). In turn, digital technologies are seen as a key enabler of seamless supply chains. Supply chain integration, which includes using the same information technology systems and exchanging knowledge, is a dynamic capacity that boosts performance (Beske, Land, & Seuring, 2014).

2.11 Theory of Reasoned Action

Supply chain management (SCM) is a word that was first used in print in the 1980s (Gomm, 2008), and it was invented by logistics consultants Oliver and Webber. Strategic choices at a high hierarchical level are required for effective chain management, as emphasized by Oliver and Webber (2012), who argue that the supply chain should be seen as a coherent entity. While the phrase "supply chain management" wasn't created until much later (Felea and Albăstroiu, 2013), study on the subject dates back quite a ways. These methods are distinguished in the academic literature by the theoretical work of a select few writers in fields as diverse as logistics, marketing, and operations research.

Among the most influential works on P&D networks are those written by Bowersox (1969) on cooperation and coordination, Hanssmann (1959) on inventory management, and Forrester (1958) on the role of dynamics in P&D networks. However, since the notion of SCM was first introduced in the 1980s, academic and professional interest in the field of SCM research has steadily grown (La Londe, 1997).

This is mostly due to the fact that global rivalry has become more intense and businesses have realized they can no longer remain competitive independently of their suppliers and that cross-company collaboration offers a big competitive advantage. The SCM's application has been studied extensively over the last two decades, leading to the development of a wide range of methodologies and definitions (Gomm, 2008).

Depending on the author, SCM may be seen as either a management philosophy or a part of the management process (Tyndall et al., 1998). SCM is often defined in operational terms while considering the material and product flows. Supply chains, as defined by Christopher (1994), consist of a series of interconnected upstream and downstream entities that work together to provide goods and services to consumers. According to Chopra and Meindl (2007), the term "supply chain" refers to the network of businesses and other organizations that work together to fulfill consumer demand. Supply chains, as defined by Mentzer et al. (2001), are networks of entities that collaborate to provide goods and services to consumers. However, since its inception in the 1980s, when controlling the flow of products and information through the supply chain was its primary goal, SCM has steadily evolved, and more and more factors are now included in the management of supply chains.

2.12 Human Society Theory

Studies by Zhao, Droge, and Stank (2001) and Lynch, Keller, and Ozment (2000), among others, which examine and evaluate supply chain capabilities from a resource-oriented viewpoint, serve as the foundation for this study. Several functions associated with logistics and supply chains have been discussed and analyzed in the literature, all of which contribute to enhanced company performance and the development of a long-term competitive advantage (Zhao, Droge, and Stank, 2001; Esper, Fugate, and Davis, 2007; Olavarrieta and Ellinger, 2009).

According to Ponomarov (2012), successful businesses actively cultivate and establish such supply chain skills to boost performance and keep competitive advantages. Empirical studies, such as those conducted by Zhao et al. (2001), reveal the importance of customer focus and information focus to a company's bottom line. Interestingly, the study found that information-oriented abilities by themselves are not a differentiating element directly connected to the performance of the business. These are better put to use in the production of other, more difficult-to-replicate traits. A company's supply chain can respond effectively to SC-interruptions and other issues resulting from an unpredictable external business environment only if the optimal mix of these talents is in place (Ponomarov, 2012). Similarly, Christopher and Peck (2004, p. 13) concluded that resilience should be developed on purpose in a supply chain, and that "... there are certain features that, if engineered into a supply chain, can improve its resilience." Therefore, the purpose of this article is to explore how the presence, manifestation, and combination of certain supply chain skills affect supply chain resilience and, by extension, the performance of organizations. In what follows, we'll discuss a number of factors that have been brought up in the literature and are thought to improve supply chain performance and resilience.

H1: Agility is enhanced through Supply Chain skills and competences.

H2: Capabilities and competences in the Supply Chain, contribute favorably to Robustness.

2.13 Resilient Supply Chains

As stated by Tukamuhabwa B., Stevenson, Busby, and Zorzini (2015), p. 5599, "supply chain resilience" refers to "the adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost-effective recovery, and therefore progress to a post-disruption state of operations — ideally, a better state than before the disruption." While both Christopher & Peck (2004) and Brandon-Jones, Squire, Autry, & Petersen (2014) use identical criteria, none takes into account the time element that would indicate a rapid recovery. Given the diversity of perspectives on the subject, it's clear that there has yet to be agreement on a single definition of resilience (Purvis, Spall, Naim, & Spiegler, 2016; Tukamuhabwa, Stevenson, Busby, & Zorzini, 2015).

Due to the increasing complexity of supply chains as a result of global interactions (Gunasekaran, Subramanian, & Rahman, 2015), the importance of supply chain resilience becomes apparent when considering the various internal and external - environmental or human-induced - disruptions a supply chain is exposed to. Environmental disasters, technology advancements, key suppliers terrorism, political upheavals, and others may all cause significant financial and operational disruptions. In addition, these effects of a supply chain interruption have further repercussions, known as a "ripple effect". This is where supply chain resilience is meant to step in and lessen supply chain vulnerability and dampen the subsequent effects (Dubey R., et al., 2021).

Having a reliable supply chain has several benefits. Early detection of a disturbance is preferable since it provides more time for preparation and response. Supply networks that are resilient are able to quickly recover from by mitigating their effects. In addition, having a resilient supply chain reduces the risk of disruptions occurring. As a result of these benefits, a resilient supply chain may provide a company an edge in the market.

There are two approaches that may be taken to improve the resilience of supply networks. Belhadi et al. (2021), Tukamuhabwa et al. (2017), Wieland & Wallenburg (2013), and others categorize these methods primarily along two dimensions: proactivity and reactivity. Before a disruption occurs, proactive supply chain resilience techniques are implemented to lessen its impact or eliminate it entirely, whereas reactive methods address the disruption after it has already set in (Tukamuhabwa, Stevenson, & Busby, 2017). Concurrent supply chain resilience techniques, as mentioned by Ali, Mahfouz, and Arisha (2017), include responding to disruptions as they happen. To support these plans, it is necessary to develop competencies that will have a lasting beneficial impact on supply chain resilience (Behaldi et al., 2021). Integration, robustness, reserve capacity, and redundancy are all features of proactive strategies (Altay, Gunasekaran, Dubey, & Childe, 2018), which may be achieved, for instance, by purchasing from a variety of vendors (Gunasekaran, Subramanian, & Rahman, 2015). Digital technologies like Big data or the Internet of Things (IoT) (Gunasekaran, Subramanian, & Rahman, 2015; Belhadi, et al., 2021) allow for constant tracking, which is essential for achieving supply chain visibility in terms of information sharing. As stated by Purvis, Spall, Naim, and Spiegler (2016), "leanness" is another capacity that suggests demands are satisfied with little waste. As a last point, these skills should be tailored to each supply chain's established norms for handling risks (Christopher& Peck, 2004). Proactive supply chain resilience methods were discovered based on capabilities like integration and information exchange, and these techniques include digital connection and integrated supply chain risk management amongst supply chain partners (Belhadi, et al., 2021). As an indicator of proactive supply chain resilience capabilities, supply chain integration is the subject of this research.

Conversely, reactive capabilities are believed to be flexible ones like agility, rapidity, and reconstruction (Altay, Gunasekaran, Dubey, & Childe, 2018), however only supply chain agility is examined as such in this research. Thanks to Carvalho, Barroso, Machado, Azevedo, & Cruz-Machado (2012) both use the term "reactive capabilities" to describe this kind of skill. Supply chain reengineering, which allows for flexibility (Purvis, Spall, Naim, & Spiegler, 2016), is therefore a crucial competence for bolstering supply chain resilience (Christopher & Peck, 2004; Pavlov, Ivanov, Dolgui, & Sokolov, 2018; Tukamuhabwa B., Stevenson, Busby, & Zorzini, 2015). However, the unique context in which a supply chain operates and individual perspectives have a role in deciding which capabilities and, by extension, tactics to execute (Purvis, Spall, Naim, & Spiegler, 2016). When deciding on a supply chain resilience plan, it is also important to consider how much money it will cost to put into action (Tukamuhabwa B., Stevenson, Busby, & Zorzini, 2015).

2.14 Adaptive Supply Chains

Agility in the supply chain refers to a company's capacity to swiftly adapt its supply chain in response to shifts in demand and other external factors (Eckstein, Goellner, Blome, & Henke, 2015; Wang, Tiwari, & Chen, 2017). Meeting client demand in the most cost-effective way feasible requires swift adjustments to delivery time, design, product enhancements, product launch, and manufacturing capacity (Al-Shboul, 2017). To keep up with the ever-evolving demands of the market, supply chain agility necessitates constant communication and coordination with other supply chain partners (Braunscheidel & Suresh, 2009; Fayezi & Zomorrodi, 2015).

According to many sources (Al-Shboul, 2017; Whitten, Green, & Zelbst, 2012; Eckstein, Goellner, Blome, & Henke, 2015), supply chain agility is crucial to a company's long-term success when it comes to operational performance in highly dynamic markets. Therefore, supply chain agility is referred to by Shin, Lee, Kim, and Rhim (2015) as a strategic component that combines agile business practices across the whole supply chain, including but not limited to operational procedures, goods, services, technology, and management methods. By enhancing delivery reliability (Al-Shboul, 2017) and facilitating quicker product launch (Giannakis & Louis, 2016), supply chain agility is a far-reaching technique that speeds up the implementation of customers' fluctuating demands. Because of this, businesses are able to maintain a competitive edge in the face of erratic market conditions (Yang, 2014; Wu, Tseng, Chiu, & Lim, 2017).

Although supply chain agility has many advantages, there are still certain difficulties to be overcome in terms of setting up an agile supply chain. According to Fayezi and Zomorrodi (2015), effective information sharing across supply chain stakeholders is crucial for achieving supply chain agility. However, some businesses may worry that sharing data with their supply chain partners puts their security at risk. As a result, vital information isn't being shared, which slows down the company's ability to respond quickly to changing consumer needs (Aitken, Christopher, & Towill, 2002). Additionally, information exchange is only possible via the use of technology. Due to the fact that every company operates in its own unique setting, a wide range of options for implementing such strategies and tools exists (Arrais-Castro, et al., 2018). Therefore, it is important to investigate the potential deployment scope to make sure any expenditures are made in the best possible application (Gunasekaran et al., 2019). Because there are so many options, businesses often struggle to choose one that will allow them to communicate effectively with their supply chain partners (Aravind Raj, 2013).

2.15 Integration of the Supply Chain

According to Danese and Bortolotti (2014), supply chain integration refers to the degree to which different supply chain partners work together to boost customer satisfaction by harmonizing business processes throughout the supply chain network. Both the tactical and strategic levels of supply chain integration are deemed essential by experts (Danese & Bortolotti, 2014; Prajogo & Olhager, 2012; Leuschner, Rogers, & Schroeder, 2015).

Strategic level involves creating long-term partnerships whereas operational level involves arranging upstream and downstream flows of information and materials (Flynn, Huo, & Zhao, 2010a). Strategic connection intensity significantly influences operational integration in terms of exchanging important information and expertise, as suggested by Prajogo & Olhager (2012) and

Cagliano, Caniato, & Spina (2005). In reality, there are two facets to information exchange: the technical and the qualitative. When it comes to supply chain collaboration, the technical dimension guarantees the bare process-oriented capability of sharing data via IT-systems, while the quality dimension depends on the competencies of the supply chain partner in terms of how benefits are effectively generated from the shared information. Collaborative learning amongst supply chain partners is an iterative process that is necessary for achieving success in the qualitative dimension in particular (Chavez, Yu, Gimenez, Fynes, & Wiengarten, 2015).

Internal integration within the company and external integration with suppliers have been shown to positively affect a company's performance in the supply chain literature (Danese & Bortolotti, 2014; Leuschner, Rogers, & Charvet, 2013; Wiengarten, Humphreys, Gimenz, & McIvoer 2016; Wong, Snacha, & Thomsen 2017). Some potential advantages of internal integration include the sharing of up-to-date production information across different departments and the maintenance of accurate stock levels at all times (Flynn, Huo, & Zhao, 2010a). Sharing production schedules, demand forecasting, and collaborative problem-solving have external advantages, though (Wiengarten, Pagell, Ahmed, & Gimenez, 2014). Strategically speaking, supplier external integration enables the focus business to collect intraorganizational competences that permit cooperative product creation and harness innovation prospects (Petersen, Handfiled, & Ragatz, 2003).

In light of this, Zhu, Krikke, and Caniels (2018) argue that businesses might gain a competitive advantage by cultivating distinctive skills via tight working relationships based on constant information exchange with supply chain partners.

The literature revealed the difficulties of supplier integration that businesses confront, despite the benefits (Fawcett, McCarter, Fawcett, Webb, & Magnan, 2015; Danese & Bortolotti, 2014). First, a lack of trust between partners is a common cause of failed collaborative relationships (Day, Fawcett, Fawcett, & Magnan, 2013). Relationships with vendors often exhibit a power dynamic, according to research by Fawcett, McCarter, Fawcett, Webb, and Magnan (2015).

In fact, there is potential for conflict if the relationship between major focus enterprises and smaller suppliers becomes more asymmetric (Rokkan & Haugland, 2002). As a result, information is hidden from the supply chain network on purpose, creating a dysfunctional connection (Fawcett, McCarter, Fawcett, Webb, & Magnan, 2015). Second, IT-linkages that ease the transfer of information among the supply chain partners are crucial to the success of supply chain integration (Jitpaiboon, Dobrzykowski, Ragu-Nathan, & Vonderembse, 2013). While the majority of businesses have set up EDI and XML connectivity with their supply chain partners, just a minority of businesses provide online access to their ERP. Due to the lack of real-time data reflecting the possibly shifting requirements of the supply chain, information exchange is restricted (Bagchi, Ha, Skjoett-Larsen, & Soerensen, 2005).

2.16 Integration and resilience in the supply chain

Businesses integrate their supply chains for a number of reasons, including economic viability and the need to reduce supply chain risks in order to prevent disruptions (Jajja, Chatha, & Farooq, 2018). As Rao and Goldsby (2009) and Purvis, Spall, Naim, and Spiegler (2016) point out, the whole supply chain network has to work together to address supply chain risks and provide comprehensive solutions. According to Pettit, Fiksel, and Croxton (2010), supply chain resilience may be improved by the integration of business processes amongst various tier-levels of providers. Long-term collaboration involves creating shared objectives and exchanging data on demand projections and industry shifts (Wiengarten, Pagell, Ahmed, & Gimenez, 2014). Supply chain partners may work together toward a similar aim of proactively predicting and preventing risks by, for example, fostering tight working connections (Belhadi, et al., 2021). Rapid reaction to these ever-present supply chain disturbances is therefore made possible by the ongoing development of integrated risk management skills (Munoz & Dunbar, 2015; Burnhard & Bhamra, 2011). Based on these results, we may propose the following theory:

Supply chain integration improves supply chain resilience, therefore the first hypothesis.

2.17 Adaptability and Resilience in Supply Chains

To undertake alternative delivery plans, essential to providing a robust supply chain, supply chain agility is needed, for example, to swiftly adapt the delivery schedule in case the demands have changed (Al-Shboul, 2017). Adaptive supply chain architecture is another manifestation of supply chain resilience (Um & Han, 2021). An agile supply chain has this capability because it can respond quickly to changes in demand by revising its supply chain architecture (Al-Shboul, 2017). Sharing information improves supply chain visibility (Christopher & Peck, 2004), which in turn improves the ability to adapt to supply chain disturbances. The ability to quickly identify and respond to disturbances is another benefit of agile supply chains (Juettner & Maklan, 2011). Therefore, the network can enable an agile reaction to anticipated disruptions, increasing supply chain resilience, because of greater end-to-end visibility across supply chain processes.

Purvis, Spall, Naim, and Spiegler (2016). According to several researchers (Tukamuhabwa B., Stevenson, Busby, & Zorzini, 2015), supply chain agility may be one of numerous ways to make a supply chain more robust. Based on these results, we may propose the following theory:

Susceptibility to disruption is reduced when supply chains are more agile, supporting H2.

2.17.1 The Impact of Digital Technologies on Supply Chain Agility and Resilience

Data from various points along the supply chain can be accessed in real time by digital technologies in a networked supply chain (Soroor, Tarokh, & Shemshadi, 2009; Ivanov & Dolgui, 2020a), yielding valuable insights into shifting market demands (Jagtap & Duong, 2019). IoT sensors, tracking and tracing tools, and big data analytics are all examples of digital technologies that can be used to quickly identify the causes of disruptions in a supply chain and then implement temporary fixes (Ivanov & Dolgui, 2020a; Ivanov, Dolgui, & Sokolov, 2019). Therefore, the advantage of using digital technologies to gather and analyze real-time supply chain data may magnify the positive impact that an agile response, in terms of rapidly adapting the supply chain to a disruption, has on ensuring supply chain resilience (Ivanov, Dolgui, & Sokolov, 2019). Digital technologies, such as big data, are expected to advance this relationship by combining and analyzing all this information that originates from different points in the supply chain and revealing crucial business insights (Jagtap & Duong, 2019). This is because supply chain agility requires visibility throughout the supply chain and quick reactions to disruptions to ensure resilience (Christopher & Peck, 2004). Firms may adjust product design and delivery times more quickly to suit consumer demand if they have access to data that properly represents market activity (Tao, Qi, Liu, & Kusiak, 2018). This is particularly important in uncertain markets, where customers'

needs might shift rapidly, necessitating the timely and precise modification of goods or supply chain activities to maintain the company's supply chain's long-term resilience (Tukamuhabwa B., Stevenson, Busby, & Zorzini, 2015). Based on these results, we may propose the following theory:
H5: There is a correlation between supply chain agility and resilience, but digital technologies mitigate that correlation.

2.17.2 The Role of Digital Technologies as the SC Moderator Capacity for Recovery and Effective Operation

It is suggested that resilient supply chains can both prevent disruptions from happening and quickly recover from them. By mitigating the effects of disruptions on the supply chain, a resilient supply chain contributes favorably to operational performance (Tukamuhabwa, Stevenson, & Busby, 2017). However, digital technologies like Cloud platforms are needed to easily transmit important data across the supply chain partners, allowing for more resilient adjustment to a disruption by exchanging information. When information is pooled, Big Data Analytics may be used to devise strategies for lowering lead times, which in turn boosts operational efficiency (Raji, Shevtshenko, Rossi, 2015).

Supply chain resilience may be improved by using data analytics systems as digital learning systems that refine preventative and corrective procedures in response to disturbances (Ivanov, Dolgui, & Sokolov, 2019). This leads us to hypothesize that the use of digital technology will further strengthen the correlation between supply chain robustness and operational efficiency.

Hypothesis 6: The connection between supply chain resilience and operational effectiveness is tempered by the presence of digital technology.

2.17.3 Capabilities for Risk Management

The relationship between risk management skills and resilience is not as well established in the relevant scientific literature as it is for information management capabilities or supply chain strategies (Ponomarov, 2012), despite the fact that these are both critically significant. However, risk management skills play a significant role with respect to resilience, since the development of a risk management culture inside an organization may improve or even promote the resilience feature of the supply chain (Christopher and Peck, 2004).

Cascaded failures of the supply chain may be prevented, say Wieland and Wallenburg (2012), by careful risk management at each level of the supply chain. Organizational learning from past incidents is facilitated by having strong risk management skills (Lin and Wang, 2011; Schmitt, 2011), and vice versa.

Zsidisin and Wagner (2010) state that knowing an organization's propensity for risk helps with taking precautions to lessen or eliminate its negative effects in the event of a disruption. Stronger supply chain resilience is the result of a greater focus on risk management (Wieland & Wallenburg, 2013). According to Christopher and Peck's (2004) findings, not all businesses understand the importance of resilience within the context of risk management, and more could benefit from applying a variety of risk management tools to improve resilience through more thorough identification and management of supply chain risk.

The ability to manage risks effectively improves agility, as stated in H1d.

H2d: Capabilities in Risk Management enhance Robustness.

2.18 Summary

Agility guarantees a supply chain to respond and adapt to disruptions effectively, allowing it to begin the recovery process as quickly as feasible (Hohenstein et al., 2015). A supply chain may recover from disruptions more rapidly and experience less overall damage if prompt action is taken to address them (Manuj and Mentzer, 2008). The longer a disruption impacts supply chain performance, the more time a corporation has to respond and implement remedies (Blackhurst et al., 2005). Blackhurst et al. (2011) further emphasizes the good impact agile components of resilient capabilities have on supply chain performance by drastically cutting recovery time following a disruption. Therefore, it is postulated that the resilient dimension's adaptable capabilities improve supply chain performance as a whole.

Supply Chain Performance improves when Supply Chain Agility increases, according to H3a.

According to Hohenstein et al. (2015), having a supply chain that can withstand and recover quickly from disturbances is essential to building resilience. Companies need to take a proactive approach to resilience, developing specific elements and capabilities to not only restore the supply chain to pre-disruption performance levels but even improve upon them (Hohenstein et al., 2015) in order to absorb and mitigate potential disturbances.

Organizations must understand how interruptions may be foreseen and how to best plan for and respond to disruptions, as stated by Yang et al. (2009). Companies can mitigate the negative effects of disruptions on their performance by incorporating robust strategies into their supply chain, such as slack capacities, redundancies, or safety stocks have stressed the need of foresight in spotting trends and hazards that may have a long-term impact on the core business's profitability. According to (Hallikas et al., 2004), the entire performance of a supply chain may be improved by proactive measures, particularly by predicting future risks. This is because of the belief that having access to predictive and forward-looking capabilities buys a company more time and flexibility to respond to unforeseen disruptions (Wieland & Wallenburg, 2013). Companies with strong supply chain capabilities recover more quickly and show weaker stock market responses to disruptions (Hendricks, Singhal, & Zhang, 2009), whereas organizations that have been exposed to disruptions take a long time to recover from the negative consequences (Hendricks & Singhal, 2005).

Given the above, it stands to reason that robust capabilities improve supply chain performance by mitigating the ill consequences of interruptions.

H3a: Supply Chain Performance improves as the amount of Supply Chain Robustness increases.

Based on the reviewed literature, a conceptual model is created, which establishes a connection between the antecedents of resilience and the effects of agility and robustness on supply chain performance. The model is shown in Figure 1, and its chosen hypotheses are listed.

CHAPTER III: METHODOLOGY

Methodology

The research strategy is presented in this section. Philosophy, strategy, technique, design, and literature review are all laid out here. In addition, the sampling strategy, survey design, and data collecting procedures are described in detail. Factor analysis, common method bias assessment, validity and reliability analysis, and regression analysis are then expounded upon as methods for analyzing the data. In the end, the model fit indices that were used in this study are detailed.

3.1 Overview of the research Problem

To thrive in the modern global economy, businesses must work together with their suppliers and customers to enhance supply chain efficiency, transparency, and communication. Companies are becoming more aware of their financial and operational susceptibility due to the difficulties in satisfying client demands and managing global supply networks. Unexpected disruptions to organizational operations may result in lost income and, in the worst case scenario, business shutdown. Building resilience into the supply chain may help lessen and even eliminate exposure to risks by creating plans that enable the system to swiftly return to its pre-disturbance operating condition.

In the manufacturing industry, supply chain resilience before, during, and after a pandemic has to be evaluated. Previous research lacked information on the post-epidemic environment and was mostly concerned with supply chain resilience during the pandemic. Consequently, information on the resilience of the supply chain was not given as much weight as the supply chain process. Accurate information cannot be obtained from studies selected to conclude the literature on the effect of resilient supply chain methods on the manufacturing sector. Research emphasizes other industries—such as hospitality—rather than the manufacturing sector when it comes to constructing resilient supply chains.

3.2 Operationalization of theoretical constructs

This research also examines the function of supply chain benchmarking as a possible mediating factor in the relationship between SCRE and OP. This is based on earlier study by Bhamra, Dani, and Burnard (2011), who observed that the association between SCRE and OP is influenced by a variety of variables.

Based on these variables, the study assesses how supply chain resilience affects operational performance and looks at the moderating role of supply chain benchmarking in manufacturing.

The interrelationships between the variables, the hypotheses developed to assess these ties, and the hypothesised connections among the variables Details on the methodology are given in the third chapter of the paper. Examples of these include the research design, sample size, and data analysis decisions. Chapter 4 focuses on data analysis, conclusions drawn from testing the framework and hypotheses, and discussions of these conclusions. There is also discussion of the research questions. The work is summarized in the final chapter, "Chapter Five: Conclusions and Implications for Future Research on Supply Chain Resilience and Operational Performance: The Moderating Role of Supply Chain Benchmarking," which also makes relevant recommendations for further research in this field and draws conclusions from the research findings.

We then establish the parameters of this master's thesis. We inform readers about the global disruption of the supply chain caused by COVID-19 and how it affects the manufacturing sector. We talk about the limitations and scope of this study and use these details to pinpoint the problem. The philosophical foundations of a researcher's work should be understood since they influence the study design, methodology, and, eventually, the results. In accordance with the stated research philosophy, researchers must further demonstrate that they have participated reflectively in the methodology of the study (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p. 107). There are two main components that define study philosophy as a whole: ontology and epistemology. Researchers' ontologies are reflections of their starting worldviews. Researchers have four possibilities for ontologies: nominalist, relativist, realist, and internal realist. According to Easterby-Smith, Thrope, Jackson, & Jaspersen (2018), p. 115, all facts are the result of human imagination (nominalism) combined with the conviction that there is only one reality and that it can be discovered by direct observation (realism). This research used a realist ontology because realism emphasizes quantitative observations of actual objects and facts, such as performance results (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p. 118). Consequently, the purpose of this research is to determine how supply chain resilience influences operational efficiency. By adopting this ontological perspective, the research is able to accurately depict the observable, objective reality without the need for prior assumptions.

Details about the epistemology are also provided by the chosen ontology. One of the main concerns of epistemology is how humans learn about the world (Gómez & Mouselli, 2018, p. 17). Both positivism and social constructivism represent diametrically opposed epistemic positions. The notion that there is an objective universe that can be investigated and comprehended is a cornerstone of positivism. Information is thus only considered when it can be shown to be backed by firsthand observation of the outside world (Hair, Page, & Brunsveld, 2019, p. 307). Positive research needs to develop ideas that allow for quantitative measurements in order to demonstrate the presence of causal relationships (Easterby-Smith, Thrope, Jackson).

The idea behind social constructionism, on the other hand, is that there isn't an objective reality. Reality is defined by people, not by objective facts (Easterby-Smith, Thrope, Jackson, & Jaspersen 2018, p. 122). Because it built its model of the outside world on presumptions intended to faithfully represent that reality in terms of objective facts, this research used a positivist perspective. Thus, the aim of this research was to determine the causal relationships between the variables in the conceptual model. We included and scrutinized concepts from previous studies that established the causal relationship between the variables to guarantee the precision of the developed model. In order to track the development of digital tools and supply chain competencies like agility and integration within the framework of supply resilience, this research set out to understand the viewpoints of specific respondents.

3.3 Research Purpose & Questions

The research design specifies the procedures to be followed in doing the research necessary to achieve the goals of the study (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018; Hair, Page, & Brunsveld, 2019; p. 160). Exploratory, descriptive, and causal research strategies are the three main options available. In order to determine whether or not one variable causes another, the researchers used a causal research strategy (Hair, Page, & Brunsveld, 2019, pp. 162 ff.). Thus, the question of causation is examined (Hair, Page, & Brunsveld, 2019, p. 169 ff.) to determine whether or not a change in one parameter predicts a change in another. The research technique (Hair, Page, & Brunsveld, 2019, p. 203 f.) and the epistemological perspective of the study (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p. 124), among other factors, influence the choice of research design. Quantitative research methods collect quantitative data through surveys sent to a large sample size and use either a descriptive or causal research design (Hair, Page, & Brunsveld, 2019, p. 203 ff). Qualitative research methods imply a research design that is exploratory. In this way, a positivist epistemology is associated with a causal research design, whereas social constructionism is associated with an exploratory research approach (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p. 124). Since the study follows a positivist epistemology and uses a quantitative research approach in the form of a survey sent to one enterprises, it is again recommended that respondents be carefully chosen at random.

This study will analyse and evaluate the SCR related to the COVID-19 disruption with input from the manufacturing sector..

3.4 Research Design

Quantitative and qualitative research methodologies are two options for conducting a study (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p. 125). Which research strategy is most appropriate depends on the epistemology and ontology that is selected. Realist ontology implies positivist epistemology, which suggests a quantitative research technique (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p. 111 ff.), while nominalist ontology is associated with a constructionist epistemology, which necessitates a qualitative research approach. Textual or visual data, collected informally via observation or interviews, is the basis of a qualitative research approach. On the other hand, quantitative research relies on the statistical analysis of data that can be quantified numerically or at least appraised objectively. Therefore, in order to put theories to the test, a quantitative research approach is used. Financial reports, surveys, and sales reports are all good places to look for quantitative data. There are a variety of positive outcomes that may be attained by the use of quantitative research techniques (Hair, Page, & Brunsveld, 2019, pp. 161 ff). The study's findings are believed to be generalizable (Hair, Page, & Brunsveld, 2019, p. 161) since quantitative data is collected from a large sample and is straightforward to organize. Because of this, quantitative research findings are generally considered when implementing new regulations (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p.129). Data obtained quantitatively, whether in the form of figures or ratings, is often seen as being more objective than data acquired qualitatively since it requires no interpretation on the part of the researcher. Therefore, impartiality is preferred when conducting hypothesis tests (Hair, Page, & Brunsveld, 2019, p. 161 ff).

The purpose of this study is to examine the impact of digital technologies on supply chain integration and agility, as well as the impact of supply chain resilience on operational performance. As a result, hypotheses are tested statistically based on the correlations between variables that are represented graphically in a model (Hair, Page, & Brunsveld, 2019, p. 174). The hypothesized correlations to be examined in this investigation are shown in Figure 1. This study draws inferences about the whole population of manufacturing enterprises based on the representativeness of the sample and the objectivity of the data collected (Hair, Page, & Brunsveld, 2019, p. 161).

3.5 Population and Sample

Primary data and secondary data are both viable options for a quantitative investigation. Researcher-conducted surveys and in-person observations are two examples of primary data collection methods. Primary data, on the other hand, is newly collected and not previously available in any form (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018). Primary data for this research was gathered with the use of a web-based survey that automatically saves responses (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018). Self-completion methods are those in which respondents are responsible for completing the survey on their own time (Hair, Page, & Brunsveld, 2019; Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018). When doing research using primary sources, researchers have more control over the quality of their data because they may choose a sample and focus their questions in a way that is most relevant to their research goals

(Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018). Because of these merits, primary data collecting was used in this investigation.

3.6 Participants Selection

In an ideal research situation, information would be collected from every member of the target population. Since this is usually impractical owing to factors such as cost, time, and accessibility, a sample is taken from the population instead. The findings from the sample data are extrapolated to the whole population. Consequently, the sample size has to be sufficiently large (Hair, Page, & Brunsveld, 2019, p. 179 ff).

Manufacturing companies were chosen because they are pioneers in the "Industry 4.0" revolution, which emphasizes the integration of information and communications technology into business operations (Kagermann, Lukas, & Wahlster, 2011). Only manufacturing companies with more than 50 workers were included in the sample to guarantee a sufficient degree of digital technology. Probability sampling, a standard method for selecting a statistically valid sample in quantitative research (Hair, Page, & Brunsveld, 2019), was used to choose the sample of 500 manufacturing enterprises. To this end, researchers often determine in advance what percentage of the target population will be included in their samples (Hair, Page, & Brunsveld, 2019). Stratified sampling, a subset of probability sampling, is used in this case. The benefit of this method is that the sample data is more reliable, and it does not cost any more to conduct than other methods. The first step of the stratified sampling method is to split the population to be sampled into distinct groups (Hair, Page, & Brunsveld, 2019). For this reason, the 1000 manufacturing enterprises were categorized in this research according to their total number of workers. The proportionality or disproportionality of stratified sampling is a matter of choice. This research makes use of a kind of sampling known as proportional stratified sampling. As a result, the number of elements chosen for the sample of each subset is proportional to the proportion of that subset in the target population, which is calculated by multiplying the total number of elements in the target population by the percentage of elements in the subset in question.

The overall size of the sample is equal to the sum of the sizes of the subsamples (Hair, Page, & Brunsveld, 2019). Elements for the sample are selected at random from inside each subset (Hair, Page, & Brunsveld, 2019), such that each subset's elements have an equal chance of being selected. One benefit of this method is that it encourages researchers to seek out objective data and choose a sample that is really representative of the whole.

3.7 Instrumentation

It is common practice to ask respondents a series of questions in the form of a questionnaire. Everyone who participates in the study is asked the same set of questions in the same order. Because of its many benefits, a structured questionnaire was choose to be used in this study. To begin, a survey may collect a large quantity of information from many people in a short length of time. Second, with the help of appropriate statistical tools, the results of the survey may be readily quantified. Finally, the results may be examined more objectively than with other research methodologies. Both open-ended and closed-ended questions may be used in surveys for business research. Close-ended questions are used in quantitative research to provide respondents with a set of options that have already been established (Dalati & Gómez, 2018, p. 184).

Both firm size and revenue from the most recently completed fiscal year are used as controls in this analysis. Digital technologies, supply chain agility, supply chain integration, supply chain resilience, and operational performance are all discussed in the second section, which consists of closed-ended questions. Here, we corroborate preexisting correlations by drawing questions (items) for each component from research that used structural equation modeling to guarantee content validity. Respondents were given a five-point Likert scale, with 1 representing "Strongly disagree" and 5 representing "Strongly agree," on which to rate the questions. Ordinal scales, such as the Likert scale (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018) allow for a range of answers from strongly disagreeing to strongly agreeing. The questionnaire used in this study was back-translated by a multilingual supply chain manager to guarantee accuracy.

The completed items utilized in the regression analysis are listed. After doing the analysis, certain items were eliminated from the former because they did not meet the criteria for validity or reliability.

Several seasoned specialists in operations management were asked to assess the questionnaire and provide improvements to increase its face validity. Minor adjustments were made to the questionnaire based on their comments to increase its validity and make it easier to understand. Finally, a pilot study involving 50 businesses was carried out to further investigate the reliability of the survey.

All research variables were needed to be assessed using the COVID-19 framework.

In other words, everything about the criteria for measurement has to account for the conditions at COVID-19.

Standardized scales (Dalenogare et al., 2018; Mittal et al., 2018; Frank et al., 2019; Li et al., 2020) served as the basis for the digital technologies' measurement items. In particular, we wanted to know how far respondents' companies had taken the use of big data, cloud computing, IoT, and analytics technologies in light of the current COVID-19 epidemic. Smys & Raj (2019) and Li et al. (2020) argue that the development of these four digital technologies together may result in greater aggregation advantages.

Components for internal, external, and customer integration were sourced from See also: Flynn et al. (2010), Wong et al. (2011), and Narasimhan & Kim (2002). In the sections on supplier integration and customer integration, respondents were asked to assess the extent to which their businesses supported and cooperated with customers/suppliers in areas such as information exchange, collaborative planning, strategic alliances, product development, etc. The degree to which respondents agreed with statements on the responsiveness of all departments to other departments within their organizations, integrated system application, information flow management, and physical flow management was also used to evaluate internal integration.

The firm resilience measurement scale is based on previous work by Ambulkar et al. (2015), Ali et al. (2017), and Parker & Ameen (2018). The firm's capacity to recover quickly from supply chain interruptions and implement necessary adjustments was utilized as a metric. Firms' capacity to bounce back from setbacks and understand the bigger picture and future direction of supply chain operations were also factored in. Complexity metrics were borrowed from Li (2016), Huang (2000), and Tsai et al. (2008). We used the authors' three-item scale for gauging the informational challenges of people and applied it to businesses. Participants were asked to provide examples of the informational challenges that companies face, such as the volume of data, the complexity of supply chain data, and the breadth of informational dimensions.

We used the number of workers and yearly revenue of the companies as measures of firm size for the variables. Researchers have used sample size as a proxy for resilience in previous studies (Gu et al., 2021a). Greater competitiveness and resource advantages, as well as the ability to achieve resilience, are hallmarks of bigger organizations compared to smaller ones (Huo et al., 2015; Azadegan et al., 2020). In addition, we eliminated any bias introduced by the ownership structure of the company by controlling for it (Liu et al., 2014; Amoako-Gyampah et al., 2019).

3.8 Data Collection and Procedures

The research methodology refines the connection between theory and empirical evidence. Research methods such as induction, deduction, and abduction are covered (Kennedy, 2018, pp. 49 ff). A deductive methodology was used for this study. Therefore, unlike induction, this study did not uncover previously unknown occurrences. Instead, a novel empirical setting was used to test for the presence of causal links between previously researched variables (Kennedy, 2018, p. 50). The following procedures were carried out, as shown in Figure 2, in line with logical reasoning. A literature study was performed, and a conceptual model was built based on previously established causal links, all through the lens of dynamic capacities. Second, inferences were drawn from the connections between variables. After that, questionnaires were sent to businesses in industrial sector to collect the necessary information. Questions from prior research were included in the survey. In the end, survey data was used to assess the hypotheses. SPSS was used to perform statistical analysis and quality control on the data presented here.

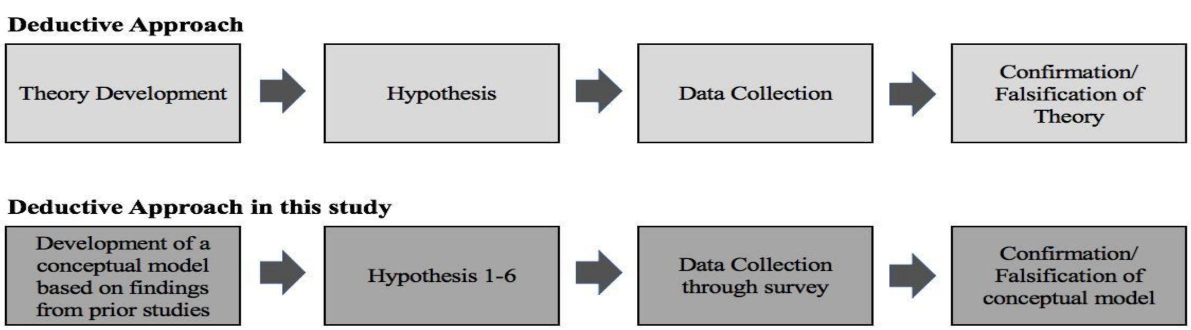


Figure 3. 1: Research Approach

Source:
https://www.google.com.sg/books/edition/Reason_Rigor/QYQQKQkL8d8C?hl=en&gbpv=1&dq=reason+and+rigor+by+sage&printsec=frontcover

3.9 Data Analysis

Finding the links between factors is the ultimate goal of inferential surveys. Therefore, it is important for researchers to identify the causal factors at play. This implies that identifying the dependent and independent variables is necessary. The influence on the dependent variables is attributable to an independent variable. Accordingly, what scientists are interested in predicting is the value of the dependent variable (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p. 169). Furthermore, it is recommended in more intricate statistical models that examine if the strength of the association between an independent and dependent variable may be improved by including a third variable, a so-called moderator variable (King, 2013).

There are two sections to this study. In the first section, we examine how supply chain skills, namely agility and integration, affect supply chain resilience. Thus, resilience is the dependent variable, whereas supply chain agility and integration are the independent factors. In addition, the role of digital technology as a moderator is studied in the context of the connections between supply chain agility and resilience, and between supply chain integration and resilience. Part 2 examines how supply chain resilience affects operational performance, where the former is an independent variable and the latter is a dependent one. In this context, we also examine the role that digital technologies play as a moderator variable between supply chain resilience and operational performance.

In addition, new control variables were included. In order to lessen the likelihood of confounded results that undermine the validity of the created model, control variables are included in the investigation of causal linkages (Atinc, Simmering, & Kroll, 2012). Control variables are kept constant during statistical testing since they reflect typical features of a company's operation that affect its performance (Pervan, Pervan, & urak, 2017). The regression analysis in this study included control factors such as business age, firm income from the previous fiscal year, and company size. Researchers in the past have often utilized firm size and revenue as proxies for other factors. The bigger a company is, the more likely it is that it has the means and capacity to invest in digital technologies or activities connected to the supply chain (Li, Dai, & Cui, 2020).

Data analysis is the process of thoroughly evaluating the main data collected from the questionnaire using statistical techniques. Descriptive statistics and inferential statistics are taken into consideration as methods of data analysis. Descriptive statistics are used to summarize and describe the study's data. Data were analyzed (through data screening) and the characteristics of the sample were tabulated using descriptive statistics (Aboujaoude, Feghali, & Kfouri, 2018). In addition, inferential statistics were used as part of the quantitative research approach to extrapolate findings from the sample to the whole population. Using a model and hypothesis testing, inferential statistics attempts to discover tendencies, patterns, and probable correlations between variables (Aboujaoude, Feghali, & Kfouri, 2018). A factor analysis was first performed to reduce the high number of observable variables into a smaller number of components (Yang H., 2012). Regression analysis was carried out to assess the presupposed relationships (Aboujaoude, Feghali, & Kfouri, 2018). SPSS, a statistical package, was used for all analyses.

Screening the data and identifying any out-of-the-ordinary answers after data collection is recommended prior to data analysis. Several different kinds of screening procedures may be used. First, while looking for outliers, descriptive statistics should be used taking into consideration the spread of how each item was categorised (DeSimone, Harms, & DeSimone, 2015). Responses that were beyond the middle 50% of the distribution were deemed severe in this research. At the same time, this research didn't include several questions since they had a response rate of less than 25%. When a value was absent, the average of the other values for that item was substituted. Second, as recommended by DeSimone, Harms, and DeSimone (2015), data from individuals who only answered to certain items and when replies for other items are absent should be discarded. In this research, this meant that respondents who did not fill out more than 25% of the questionnaire were not included in the final tally.

3.9.1 Research Design limitations

The research is limited to a fixed number of respondents and is also impacted by the biases of the respondents and their knowledge.

3.9.2 Conclusion

In order to combine the data and make the subsequent analysis more manageable, a factor analysis is performed. Consequently, a number of interconnected elements are collapsed into a smaller number of elements (Hair, Page, & Brunsveld, 2019). This research used the principle components analysis (PCA), one of the two most popular factor analysis methods (the other being the common factor analysis; see Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, pp. 445 ff.). Through a process known as principle components analysis, a large set of data may be reduced to a manageable subset of variables. This means that the initial variance may be explained by a smaller set of principle components (Hair, Page, & Brunsveld, 2019, p. 428). Individual survey questions were used to reflect these factors, which were broken down into the broad categories of "supply chain resilience," "supply chain agility," "supply chain integration," "digital technologies," and "operational performance" for the sake of this research. Principal components analysis is useful because it takes into account not just the typical but also the out-of-the-ordinary and the error variance. since of this, PCA is commonly used in business research (Hair, Page, & Brunsveld, 2019, p. 428) since it produces more reliable results.

3.9.3 Trustworthiness and Efficacy

According to the definition provided by (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018), validity is "the extent to which a concept is measured accurately in a quantitative study." Researchers use content validity and factor validity to examine a questionnaire's reliability and accuracy before using it. At start, we looked at the content validity. The content validity of a questionnaire determines whether or not it accurately measures the targeted constructs (Bolarinwa, 2015). Previous study results should be reviewed to guarantee topic validity (Saunders, Lewis, & Thornhill, 2009).

Second, we checked each item's factor validity. The so-called factor loadings are an essential product of the factor analysis. Reducing the number of items to express the correlations between factors is accomplished with the help of factor loadings (Yang H., 2012, p. 480). Factor loadings with a value of 0.6 or above are recommended for further analysis as stated by Hair, Page, & Brunsveld (2019, p. 430 ff). Items would explain at least 60% of the overall variation if this were the case. Items with a factor loading of less than 0.6 should be eliminated from consideration; however, they may be included in future study to determine whether or not they should be retained. In addition, a correlation matrix is used to examine the so-called discriminant validity, which states that unique factors should not be correlated with dissimilar ones (Hair, Page, & Brunsveld, 2019). In addition, the Kaiser-Meyer-Olkin (KMO) (Kaiser, 1970; Kaiser, 1974) test and Bartlett's test of sphericity (Bartlett, 1954) were conducted as part of the factor loading analysis. To ascertain whether or not the observed items are suitable for performing a factor analysis, the KMO test gauges the sampling adequacy of the data (SAGE Research Methods, 2012). KMO test results below 0.5 are considered inadequate, indicating that the There is insufficient data from which to do a factor loading analysis on these questions (Spicer, 2005, p. 186). If the data set is normally distributed, this may be determined by using the Bartlett test of sphericity. Additionally, it checks whether the identity matrix is identical to the correlation matrix to rule it out as a possible explanation. A p-value of less than 0.05 shows a significant difference between the correlation matrix and the identity matrix (Hadi, Abdullah, & Ilham, 2016). SPSS was used to conduct the KMO test, the Bartlett's test of sphericity, and the factor loadings, all of which were prescribed by the aforementioned sources. In section 4.3.2, we provide the findings.

Researchers should also assess the reliability of the constructs, which contributes to the questionnaire's validity (Bolarinwa, 2015). Cronbach's alpha may be used to test for reliability (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p. 185), which measures the internal consistency of a measurement within a group of items. Cronbach's alpha was calculated using a reliability analysis in SPSS for this study. Reliability analysis was conducted independently for each factor using the factor analysis's findings on the number of items remaining in each component. Cronbach's alpha values between 0.8 and 0.9 suggest strong reliability and, by extension, high internal consistency within a group of items, as stated by the rule of thumb by Hair, Page, & Brunsveld (2019, p. 262). Reliability levels between 0.7 and 0.8 are regarded excellent, with values between 0.6 and 0.7 being acceptable. We cannot accept values below 0.6 since we do not know whether or not the entries inside the set are internally consistent.

3.10 Analyzing with a Regression

Regression analysis is used to determine the linear connections between two or more variables. Thus, the correlation of the variables establishes the existence and intensity of a link (Hair, Page, & Brunsveld, 2019, p. 395). Hypotheses are formulated and then evaluated to see whether there is a connection between these factors. The so-called null hypotheses in this scenario assert that there is no connection between the variables. The null hypothesis is rejected and the alternative hypothesis, which states that there is a link between the variables, is verified if the alternative hypothesis is statistically significant (Hair, Page, & Brunsveld, 2019, p. 383). As stated by Hair, Page, and Brunsveld (2019, p. 403), statistical significance is shown when the p-value is less than 0.05.

Different from a bivariate analysis, which only looks at the correlation between two variables, a multiple regression analysis looks at the correlation between many independent variables that predict a single dependent variable. In this way, we may evaluate how various explanatory factors affect the dependent variable of interest. Multiple regression analysis is preferable to univariate regression because it considers a more realistic model by taking into consideration a larger number of independent variables (Hair, Page, & Brunsveld, 2019, p. 401). That's why researchers here used a multiple regression analysis, too. The dependent variable in such a model is represented on a continuous scale, whereas the independent variables might be either continuous or categorical (Easterby-Smith, Thrope, Jackson, & Jaspersen, 2018, p. 521). Supply chain agility, supply chain integration, and supply chain resilience are the independent variables in this model, whereas operational performance and supply chain resilience are the dependent variables. The role of digital technology as a moderator in the link between independent and dependent variables is explored.

Table 3. 1:Questionnaire Part A

Supply chain processes	**Supply chain functions**	**Example of digital technology adoption**	**Related papers**
Product design	General product design	The real-time data collected through IoT devices in supply chain can improve product development.	(Yerpude and Singhal, 2018)
	User involved product design	The digital supply chain can enable the open innovation that includes user and supplier into the product development	(Reeves et al., 2011; Holmström et al., 2016; Chavez et al. 2017)
Demand management	Demand forecasting	Big data predictive analysis is used for demand forecasting in the pharmaceutical industry.	(Min, 2010; Waller and Fawcett, 2013; Seethamraju, 2014; Caro and Sadr, 2019;Shafique et al., 2019)
Procurement	Supplier selection	Big data analysis can forecast margins for different supplier and optimize the selection of supplier. After that, digital procurement system can inform the selected supplier promptly.	(Sanders et al., 2016; Boone et al., 2017; Moretto et al., 2017)
	Procurement decision making	Artificial intelligence is used in procurement decision making especially in the ambiguous tasks. The AI system can use different solutions according to different level of task ambiguity to increase the accuracy.	(Nissen and Sengupta, 2006; Min, 2010; Moretto et al., 2017)
	Sourcing cost reduction	Online digital procurement collaboration system can help to forecast the orders and reduce the cost of negotiation process.	(Yan, Chien, et al., 2016)

	Production planning	With direct digital manufacturing, product-centric control and IoT can simplify production planning and material handling and recovery.	(Lyly-Yrjänäinen et al., 2016; Fang et al., 2016)
Manufacturing	Quality management	Sensor technologies combining with telematics and digital services can ensure the quality of manufacturing.	(Verdouw et al., 2013; Teucke et al., 2018)
	Equipment maintenance	Use digital technology to diagnostics and prognostics equipment. IoT technology can be used to track the location of every equipment.	(Arya et al., 2017)
	Digital manufacturing	The implementation of digital manufacturing in the complex product supply chain will change the relationship between firms, OEMs and logistic service providers.	(Holmström and Partanen, 2014; Arya et al.,2017)
Warehousing and logistics	Storage assignment Inventory control and planning	Visual control used in the warehouse can collect the data of real-time inventory. RFID label can automatically identify and track material information. Assignment can be completed after the calculation in the cloud platform	(Lyly-Yrjänäinen et al., 2016; Choy et al., 2017; Hopkins and Hawking, 2018; Yu et al., 2017; Min, 2010)
	Logistics planning	Big data analysis can support routing optimization, real-time traffic operation monitoring and proactive safety management.	(Lai et al., 2010; Graham et al., 2015; Hahn and Packowski, 2015; Badia-Melis et al., 2018; Hopkins and Hawking, 2018;

			Nguyen et al., 2018)
General Supply chain	E-business process	The digital retailer platform can be regarded as a new business model that changes the supply chain structure among supplier and consumers.	(Ittmann, 2015; McIntyre and Srinivasan, 2017; Hänninen et al., 2018)
	Traceability of business process	Implementation of a traceability system in a product line can improve the overall quality of the product and minimize the impact of a product recall. The digital retailer platform can be regarded as a new business model that changes the supply chain structure among supplier and consumers.	(Campos and Míguez, 2006; Yan, Yan, et al., 2016; Li et al., 2017; McIntyre and Srinivasan, 2017; Hänninen et al., 2018; Garcia-Torres et al., 2019)
	Customer relationship Management	Use data mining system to discover the knowledge from customer base. Implementation of a traceability system in a product line can improve the overall quality of the product and minimize the impact of a product recall.	(Min, 2010)

Source: Questionnaire development by Gaurav Bhardwaj ©

Table 3. 2:Constructs, Definitions, and Sources

Construct/Items		Definition	Indicator	Adapted from
SCD				
SCD1	Digital products and Services	Products and services based on digital technology that bring digital capabilities to consumers	We have adopted digital products and services	Ageron et al. (2020) Hallikas et al. (2021) Weking et al. (2020) Frank et al. (2019)
SCD2	Digital operation process	Management and operation mode based on digital technology, including digital manufacturing, digital working and so on	We have adopted digital operation management	
SCD3	Digital business model	Business models based on digital technology, including mass customization, product service systems, open innovation and so on	We have adopted digital business model	

Source: Questionnaire development by Gaurav Bhardwaj ©

Table 3. 3: Items and Sources

Items		**Sources**
DT	**Digital technologies**	Dalenogare et al., (2018), Frank et al., (2019), Li et al., (2020) and Mittal et al., (2018)
DT1	The extent to which our firm has implemented Internet of Things in operations	

DT2	The extent to which our firm has implemented cloud computing in operations	
DT3	The extent to which our firm has implemented big data in operations	
DT4	The extent to which our firm has implemented analytics in operations	
CI	**Customer integration**	Flynn et al., (2010), Narasimhan & Kim (2002), Seo et al., (2014) and Wong et al., (2011)
CI1	We have a high level of information sharing with major customers about market information.	
CI2	We share information with major customers through information technologies.	
CI3	We have a high degree of joint planning and forecasting with major customers to anticipate demand visibility.	
CI4	Our customers provide information to us in the procurement and production processes.	
CI5	Our customers are involved in our product development processes.	
SI	**Supplier integration**	Flynn et al., (2010), Narasimhan & Kim (2002), Seo et al., (2014) and Wong et al., (2011)
SI1	We share information with our major suppliers through information technologies.	
SI2	We have a high degree of strategic partnership with suppliers.	

SI3	We have a high degree of joint planning to obtain rapid response ordering processes (inbound) with suppliers.	
SI4	Our suppliers provide information to us about production and procurement processes.	
SI5	Our suppliers are involved in our product development processes.	
II	**Internal integration**	Flynn et al., (2010), Narasimhan & Kim (2002), Seo et al., (2014) and Wong et al., (2011)
II1	We have a high level of responsiveness within our plant to meet other departments' needs.	
II2	We have an integrated system across functional areas of plant control.	
II3	Within our plant, we emphasize information flows amongst purchasing, inventory management, sales, and distribution departments.	
II4	Within our plant, we emphasize physical flows amongst production, packing, warehousing, and transportation departments.	
FR	**Firm resilience**	Ali et al., (2017), Ambulkar et al., (2015) and Parker & Ameen (2018)
FR1	We are able to manage changes brought by the supply chain disruption.	
FR2	We are able to adapt to supply chain disruptions easily.	
FR3	We are able to provide a quick response to supply chain disruptions.	

FR4	We are able to maintain high situational awareness at all times.	
IC	**Information complexity**	Li (2016), Huang (2000) and Tsai et al., (2008)
IC1	The information on the supply chain is complex	
IC2	The information on the supply chain is crowded	
IC3	The information on the supply chain is large in scale	

Source: Questionnaire development by Gaurav Bhardwaj ©

Table 3. 4 : Supply Chain Orientation

Supply Chain Orientation – adapted from Ponomarov 2012, Wieland and Wallenburg (2013)										
	During Covid					**Post-Covid**				
	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1. Joint decision making, CPFR, knowledge sharing, benefit sharing, VMI, etc. are just a few examples of the customer-focused initiatives that our company has implemented and is pursuing.	**1**	**2**	**3**	**4**	**5**					
2. We have faith in our most important clients.	**1**	**2**	**3**	**4**	**5**					

3. Our goals align with those of our most valuable clients.	**1**	**2**	**3**	**4**	**5**					
4. Executives stress the need of open communication with clients and a commitment to long-term partnerships.	**1**	**2**	**3**	**4**	**5**					
5. Our supply chain is an integrated ecosystem that allows for end-to-end communication between orders, stock, shipping, and distribution.	**1**	**2**	**3**	**4**	**5**					

Source: Questionnaire development by Gaurav Bhardwaj ©

Table 3. 5:Information Management Capabilities

Information Management Capabilities – adapted from Ponomarov 2012, Wieland & Wallenburg 2013						
	During Covid					**Post Covid**
1. One of the strengths of our company is the prompt and efficient communication of operating information across different divisions.	**Strongly Disagree**	**Disagree**	**Strongly Disagree**	**Disagree**	**Strongly Disagree**	
2. We regularly and promptly update chosen external clients on the status of our operations.	**1**	**2**	**1**	**2**	**1**	

3. The data we have at our company is reliable.	**1**	**2**	**1**	**2**	**1**	
4. Our company uses a unified database for both internal and external data exchange and communication with clients.	**1**	**2**	**1**	**2**	**1**	
5. We have complete use of all supply chain joint planning systems.	**1**	**2**	**1**	**2**	**1**	

Source: Questionnaire development by Gaurav Bhardwaj ©

Table 3. 6:Supply Chain Management Strategies

Supply Chain Management Strategies – adapted from Tang 2006, Christopher &Peck (2004), Ponomarov & Holcomb (2009)										
	During Covid **Agree**					**Post Covid**				
1. We deploy a flexible supply base approach (dual-sourcing, multiple sourcing) for our most important and mission-critical components.	**1**	**2**	**3**	**4**	**5**					
2. Our company keeps "just in case" buffer stocks of some essential components.	**1**	**2**	**3**	**4**	**5**					
3. Our company has operational buffers or spare capacity to deal with the unexpected.	**1**	**2**	**3**	**4**	**5**					

4. To put off the moment of product diversification, postponement tactics including standardization, commonality, and modular design approaches are used.	**1**	**2**	**3**	**4**	**5**					
5. We use adaptable transportation strategies (such as using numerous modes of transport, carriers, or routes).	**1**	**2**	**3**	**4**	**5**					
6. We place a premium on implementing Lean and Just-in-Time methods (5S, Six Sigma, Kanban, One-Piece-Flow, etc.) and are committed to maximizing productivity while minimizing waste.	**1**	**2**	**3**	**4**	**5**					

Source: Questionnaire development by Gaurav Bhardwaj ©

Table 3. 7:Risk Management Capabilities

Risk Management Capabilities– adapted from Ponomarov 2012, Lavastre,Gunasekaran, Spalanzani 2012										
During Covid						**Post Covid**				
1. We have a person or group whose only responsibility is to control potential threats to our company's supply chain.	**1**	**2**	**3**	**4**	**5**					

2. We use What-If Analysis, Scenario Planning, and Value Stream Mapping to help us find and evaluate potential risks.	**1**	**2**	**3**	**4**	**5**					
3. We use risk analysis tools in our business (including Pareto charts, A-B-C rankings, and FMECA, or Failure Mode, Effects, and Criticality Analysis).	**1**	**2**	**3**	**4**	**5**					
4. Our company uses methods to back up the selection and execution of risk management measures (Business Continuity Plans, etc.).	**1**	**2**	**3**	**4**	**5**					
5. Our company does proactive risk monitoring (audits, project risk reviews).	**1**	**2**	**3**	**4**	**5**					

Source: Questionnaire development by Gaurav Bhardwaj ©

Table 3. 8:Agility

Agility– adapted from Wieland & Wallenburg (2013), Ponomarov 2012 **Please indicate the speed of reaction with which your company can engage in the following activities should changes occur.**										
During Covid						**Post Covid**				
1. Modify production schedules in tandem with clients	**1**	**2**	**3**	**4**	**5**					
2. To better serve your customers, you should	**1**	**2**	**3**	**4**	**5**					
3. Modify client confidence in delivery dependability	**1**	**2**	**3**	**4**	**5**					
4. Maintain flexibility in response to										

changing market demands	**1**	**2**	**3**	**4**	**5**					
5. Resuming normal product flow after an interruption	**1**	**2**	**3**	**4**	**5**					

Source: Questionnaire development by Gaurav Bhardwaj ©

Table 3. 9:Robustness

Robustness – adapted from Wieland & Wallenburg (2013), Ponomarov 2012 **To what extent do the statements apply to your supply chain?**										
	Pre Covid					**Post Covid**				
1. Our supply chain has been quite steady for a long time, with few noticeable deviations from the status quo.	**1**	**2**	**3**	**4**	**5**					
2. When unexpected events occur, we have enough of time to formulate a plan of action thanks to our efficient supply chain.	**1**	**2**	**3**	**4**	**5**					
3. Our supply chain functions admirably over a broad range of conditions without requiring any special adjustments.	**1**	**2**	**3**	**4**	**5**					
4. Our supply chain is resilient, and has been able to continue operating normally despite suffering some damage for an extended period of time.	**1**	**2**	**3**	**4**	**5**					
5. Our company's supply chain can keep operating at a predetermined level of connectivity even in the face of interruption.	**1**	**2**	**3**	**4**	**5**					

Source: Questionnaire development by Gaurav Bhardwaj ©

Table 3. 10:Supply Chain Performance

Supply Chain Performance– adapted from Ponomarov 2012 (pre & post covid)					
Inconsistent **Consistent**					
1. The time it takes for our goods to reach our most important clients.	1	2	3	4	5
2. Duration of output in accordance with a predetermined timetable.	1	2	3	4	5
3. Catering to the day-to-day requirements of significant clients.	1	2	3	4	5
4. Keeping customer delivery dates as promised.	1	2	3	4	5
5. Consistently delivering the required amount of product.	1	2	3	4	5

Source: Questionnaire development by Gaurav Bhardwaj ©

CHAPTER IV: RESULTS

4.1 RESULTS

The chapter to follow is one for the conduct of a detailed analysis of the data gathered in a way that is true to predetermined goals. This study is geared towards the impacts of the Covid 19 pandemic on the international supply chain, with the primary focus on the manufacturing sector. Pandemic has demonstrated the existence of weaknesses within the supply system, among other things, the critical role of resilience to tackle this issue. While we move into a post COVID-19 era supply chain strategies being used to create resiliency is an area that can't be neglected.

By utilizing statistical methods and analysis, we examine the effectiveness of different tactics within manufacturing to strengthen the resilience of supply chains. These components (i.e inventory management, supplier diversity, digitalization and agility) are closely analyzed to reveal their influence on efficiency. Utilization of comprehensive empirical analyses which involves surveys we intend to improve the supply chain strategies that would help to diminish risks and realize the resilience.

Similarly, our investigations automatically evaluate the changing flow of production as a result of the pandemic by carefully scrutinizing the supply chain management strategies that emerge to tackle the coming obstacles. We plan to achieve this through a comprehensive examination our results that will give manufacturing organizations practical recommendations for actions through our findings. The analysis will allow them to have the capacity to build up the supply chain of their companies from both the epidemic and post-epidemic periods perspective.

Comprehending the significance of supply chain resiliency and strategic management is crucial for those businesses that operate in the times of uncertainty. In the process of major changes and transformations of the global economy communication and resilient supply chain strategies are of paramount importance for organizations in order to keep their success and prosper at the market level.

4.2 GRAPHICAL PRESENTATION FOR RESEARCH QUESTIONS

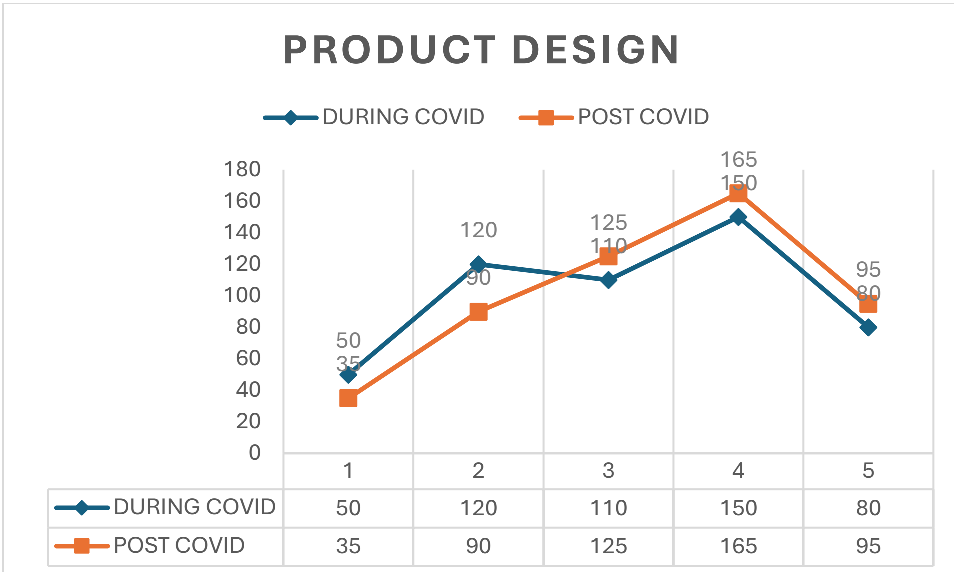


Figure 4. 1:Product design

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 1:Product design		
Frequency		
	DURING COVID	POST COVID
1	50	35
2	120	90
3	110	125
4	150	165
5	80	95

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents average product design scores during and post-COVID

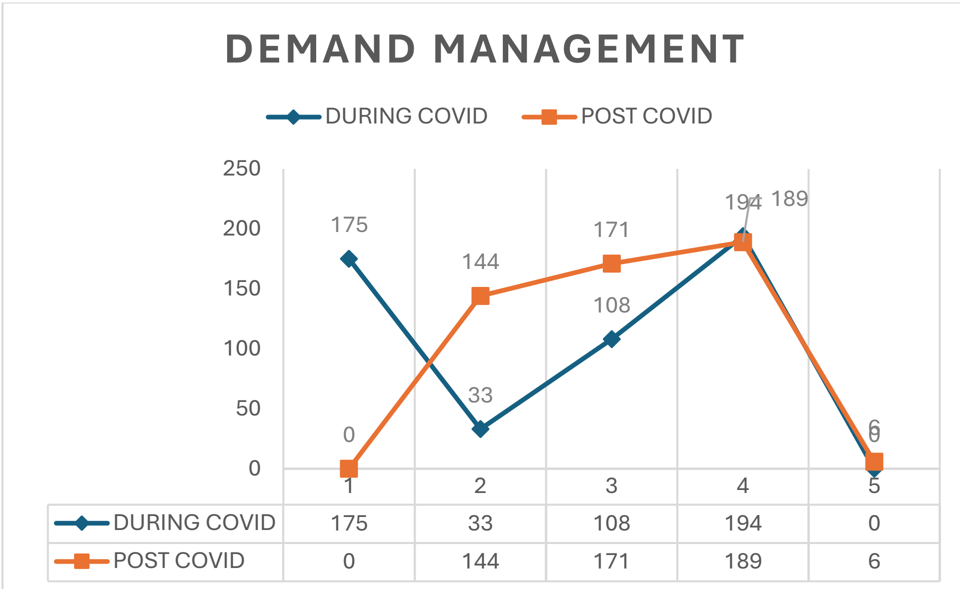
During COVID: The average product design scores show a range from 50 to 150. There is considerable variability in the scores, indicating mixed effectiveness in the application of IoT devices in supply chains and digital supply chain innovations. The highest score of 150 suggests that in some cases, organizations successfully utilized these technologies to improve product development. However, the presence of low scores (as low as 50) indicates that other organizations struggled with the implementation or effectiveness of these technologies during COVID.

Post COVID: The average product design scores range from 90 to 165, showing an even wider variation compared to during COVID. The highest score of 165 signifies a significant improvement in some organizations' use of IoT and digital supply chain innovations to enhance product development. The presence of low scores (as low as 35) still indicates challenges in some areas, but the overall trend points to a substantial increase in effectiveness post-COVID.

Summary

- **During COVID**: The scores reflect mixed success with IoT and digital supply chains, ranging from very low to moderately high.
- **Post COVID**: There is a broader range of scores, with some organizations showing dramatic improvements in effectiveness, while others continue to face challenges.

This interpretation suggests that post-COVID, organizations have generally enhanced their capabilities in leveraging IoT and digital supply chains for product development, although some variability and challenges remain.



Source: Questionnaire response - Gaurav Bhardwaj ©

Figure 4. 2:Demand Management

Table 4. 2: Demand Management		
Frequency		
DURING COVID		POST COVID
1	175	0
2	33	144
3	108	171
4	194	189
5	0	6

Source: Questionnaire response - Gaurav Bhardwaj ©

The data provided represents demand management frequencies during and post-COVID in a supply chain context.

During COVID:

- The frequencies show a range from 0 to 194. The highest frequency recorded is 194, indicating a significant demand for supply chain management at certain times. The lowest frequency is 0, reflecting periods where demand management was either absent or negligible. Other frequencies such as 175, 33, and 108 highlight varying levels of demand management efforts during the pandemic. The overall variability suggests that organizations experienced fluctuating demand management challenges, with some periods requiring intense focus and others showing minimal demand.

Post COVID:

- The frequencies range from 0 to 189. The highest frequency is slightly lower than during COVID, at 189, indicating a continued but slightly less intense demand for supply chain management. The lowest frequency is 0, similar to during COVID, showing that some periods still experienced negligible demand. Frequencies such as 144, 171, and 6 suggest a more stable demand management environment, with moderate to high demand levels. The overall trend shows a reduction in extreme variations, suggesting a more balanced and consistent approach to demand management post-COVID.

Summary:

- **During COVID:** Frequencies ranged from very low to high, indicating significant variability in demand management efforts, with organizations facing both intense and negligible demand periods.
- **Post COVID:** Frequencies still show variability but with a tendency towards more stable and consistent demand management, reflecting an adaptation and stabilization in supply chain practices.

This interpretation suggests that post-COVID, organizations have generally improved their demand management strategies, resulting in a more consistent approach. While challenges remain, the reduction in extreme variations indicates a better adaptation to new supply chain dynamics.

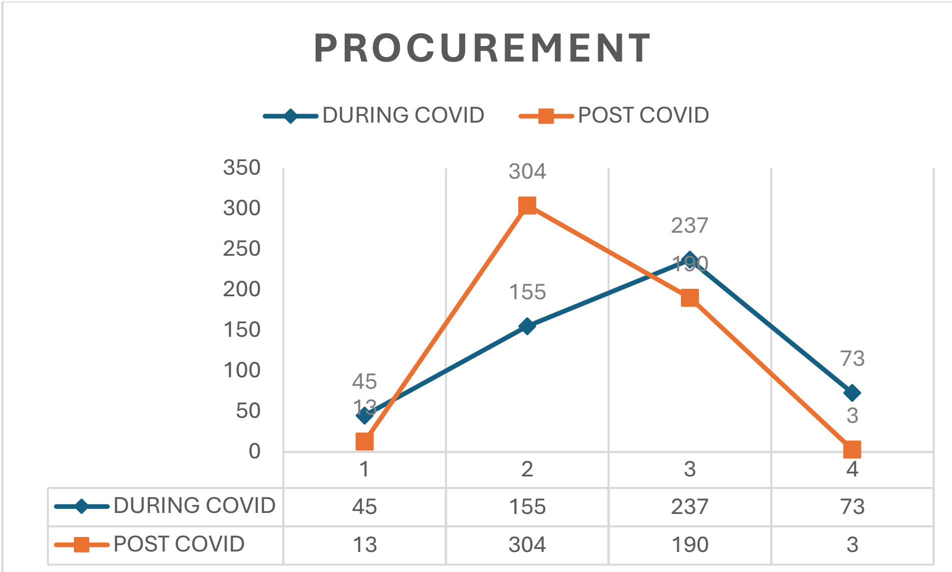


Figure 4. 3:Procurement

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 3:Procurement

	Frequency	
	DURING COVID	**POST COVID**
1	45	13
2	155	304
3	237	190
4	73	3

Source: Questionnaire response - Gaurav Bhardwaj ©

Intrepretation

During COVID: The procurement frequencies ranged from 45 to 237, with the highest frequency recorded at 237. This indicates significant procurement activity at certain times, reflecting periods where organizations faced intense procurement demands. The lowest frequency of 45 suggests periods of reduced procurement activity. Other frequencies such as 155 and 73 highlight varying levels of procurement efforts during the pandemic. Overall, the variability in procurement frequencies suggests that organizations experienced fluctuating procurement demands, necessitating intense efforts at some times while having reduced needs at others.

Post COVID: Post-COVID, the procurement frequencies show a broader range from 3 to 304. The highest frequency of 304 indicates a significant increase in procurement activity compared to during COVID, pointing to heightened procurement efforts in certain periods. Conversely, the lowest frequency of 3 shows that some periods still experienced minimal procurement activity. Frequencies such as 13, 190, and 3 suggest a more polarized procurement environment, with some periods requiring intense procurement efforts and others very little

Summary:

- **During COVID:** Frequencies ranged from moderate to high, indicating significant variability in procurement activities, with organizations facing both intense and moderate procurement demands.
- **Post COVID:** Frequencies show a broader range with a tendency towards higher procurement activity, reflecting a shift and possible increase in procurement needs. However, some periods still experience minimal procurement activity, indicating uneven demand.

This interpretation suggests that post-COVID, organizations have seen a significant shift in procurement needs, with some areas experiencing increased activity while others remain low. The increase in procurement frequencies for certain periods indicates a heightened focus on acquiring necessary supplies, possibly due to stabilizing supply chains and renewed business activities.

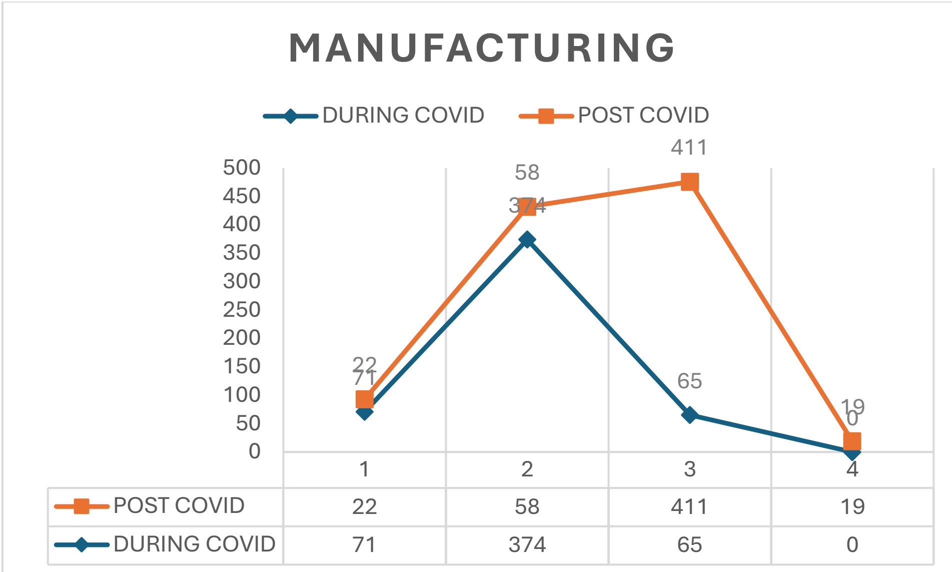


Figure 4. 4:Manufacturing

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 4: Manufacturing		
Frequency		
	DURING COVID	**POST COVID**
1	71	22
2	374	58
3	65	411
4	0	19

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents manufacturing frequencies during and post-COVID in a supply chain context.

During COVID:

- The frequencies range from 0 to 374.
- The highest frequency recorded is 374, indicating significant manufacturing activity at certain times.
- The lowest frequency is 0, reflecting periods where manufacturing activity was either absent or negligible.
- Other frequencies such as 71 and 65 highlight varying levels of manufacturing efforts during the pandemic.
- The overall variability suggests that organizations experienced fluctuating manufacturing demands, with some periods requiring intense focus and others showing minimal activity. The high variability also indicates that certain periods were marked by severe disruptions or changes in manufacturing processes and capabilities.

Post COVID:

- The frequencies range from 19 to 411.
- The highest frequency is 411, indicating a substantial increase in manufacturing activity compared to during COVID.
- The lowest frequency is 19, showing a minimal level of manufacturing activity, but higher than the lowest point during COVID.
- Frequencies such as 22 and 58 suggest a more stable manufacturing environment, with moderate to high manufacturing activity in some periods.
- The overall trend shows a significant increase in manufacturing activities, indicating a recovery and potential growth in manufacturing demands post-COVID. The range of frequencies suggests that while some periods still face challenges, the overall manufacturing landscape has stabilized and possibly improved.

Summary:

- **During COVID:** Manufacturing frequencies showed significant variability, ranging from no activity to very high activity, reflecting the severe disruptions and fluctuations in manufacturing demands and capabilities during the pandemic.

- **Post COVID:** Manufacturing frequencies indicate a broader range with a notable increase in activity, suggesting a recovery and stabilization in manufacturing demands. While challenges remain, the overall trend points to an improved and more consistent manufacturing environment.

This interpretation suggests that post-COVID, organizations have generally seen a recovery in manufacturing activities, with increased and more consistent manufacturing efforts. The substantial increase in certain frequencies indicates that manufacturing processes have adapted and possibly expanded, reflecting a positive trend in the supply chain's ability to meet manufacturing demands

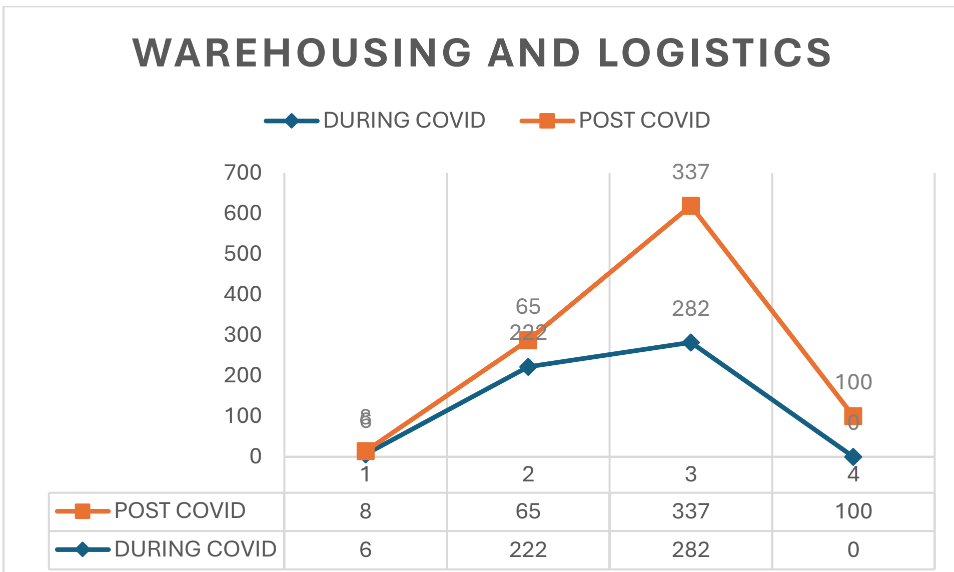


Figure 4. 5: Warehousing and Logistics

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 5:Warehousing and Logistics

Frequency		
DURING COVID		**POST COVID**
1	6	8

2	222	65
3	282	337
4	0	100

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents warehousing and logistics frequencies during and post-COVID in a supply chain context.

During COVID:

- The frequencies range from 0 to 282.
- The highest frequency recorded is 282, indicating significant warehousing and logistics activity at certain times.
- The lowest frequency is 0, reflecting periods where warehousing and logistics activity was either absent or negligible.
- Other frequencies such as 6 and 222 highlight varying levels of warehousing and logistics efforts during the pandemic.
- The overall variability suggests that organizations experienced fluctuating warehousing and logistics demands, with some periods requiring intense focus and others showing minimal activity. The high variability indicates that certain periods were marked by severe disruptions or changes in warehousing and logistics operations.

Post COVID:

- The frequencies range from 8 to 337.
- The highest frequency is 337, indicating a substantial increase in warehousing and logistics activity compared to during COVID.
- The lowest frequency is 8, showing a minimal level of warehousing and logistics activity, but higher than the lowest point during COVID.
- Frequencies such as 65 and 100 suggest a more stable warehousing and logistics environment, with moderate to high activity in some periods.

- The overall trend shows a significant increase in warehousing and logistics activities, indicating a recovery and potential growth in warehousing and logistics demands post-COVID. The range of frequencies suggests that while some periods still face challenges, the overall warehousing and logistics landscape has stabilized and possibly improved.

Summary:

- **During COVID:** Warehousing and logistics frequencies showed significant variability, ranging from no activity to very high activity, reflecting the severe disruptions and fluctuations in warehousing and logistics demands and capabilities during the pandemic.
- **Post COVID:** Warehousing and logistics frequencies indicate a broader range with a notable increase in activity, suggesting a recovery and stabilization in warehousing and logistics demands. While challenges remain, the overall trend points to an improved and more consistent warehousing and logistics environment.

This interpretation suggests that post-COVID, organizations have generally seen a recovery in warehousing and logistics activities, with increased and more consistent efforts. The substantial increase in certain frequencies indicates that warehousing and logistics processes have adapted and possibly expanded, reflecting a positive trend in the supply chain's ability to meet warehousing and logistics demands.

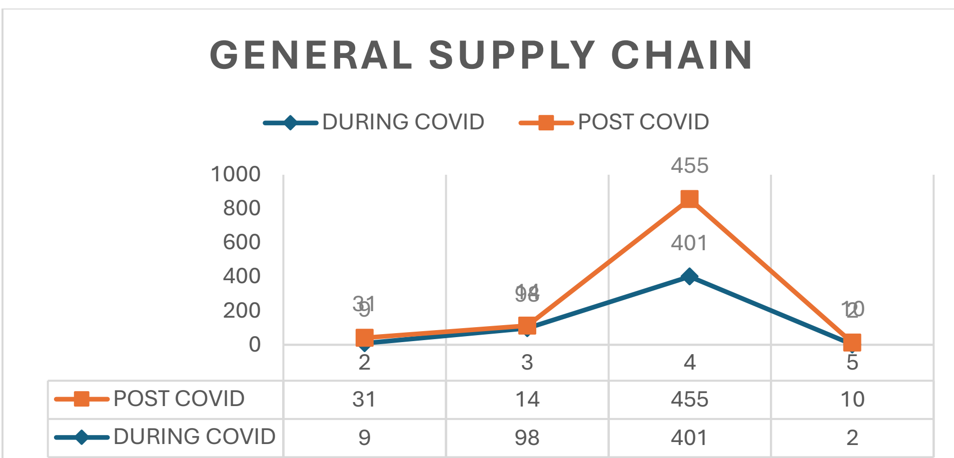


Figure 4. 6:General Supply Chain

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 6:General Supply Chain

	Frequency	
	DURING COVID	**POST COVID**
2	9	31
3	98	14
4	401	455
5	2	10

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents general supply chain frequencies during and post-COVID.

During COVID:

- The frequencies range from 2 to 401.
- The highest frequency recorded is 401, indicating peak supply chain activity at certain times.
- The lowest frequency is 2, reflecting periods of minimal supply chain activity.
- Other frequencies such as 9, 98, and 401 show varied levels of supply chain activities, suggesting fluctuating demands and operational challenges during the pandemic.
- The overall variability suggests that organizations faced significant disruptions and changes in their supply chain operations, with some periods experiencing high activity and others much less.

Post COVID:

- The frequencies range from 10 to 455.

- The highest frequency is 455, which is slightly higher than the peak during COVID, indicating continued strong supply chain activity.
- The lowest frequency is 10, showing a minimal level of activity, but still higher than the lowest point during COVID.
- Frequencies such as 31, 14, and 455 indicate a shift towards more stable and increased supply chain operations, with some periods showing high activity and others moderate levels.
- The overall trend suggests a recovery and possible growth in supply chain activities post-COVID, with an increased peak frequency indicating an adaptation to new supply chain demands and possibly improved operational efficiency.

Summary:

- **During COVID:** Supply chain frequencies displayed considerable variability, ranging from very low to very high activity, reflecting significant disruptions and fluctuations in supply chain operations during the pandemic.
- **Post COVID:** Supply chain frequencies show a broader range with a tendency towards higher and more stable activity levels, indicating a recovery and potential growth in supply chain operations. The increased peak frequency suggests improvements and adaptations in supply chain management.

This interpretation indicates that post-COVID, organizations have generally seen a recovery and growth in supply chain activities, with increased and more consistent efforts. The higher peak frequency post-COVID reflects a positive trend in the supply chain's ability to handle demands and adapt to new operational realities.

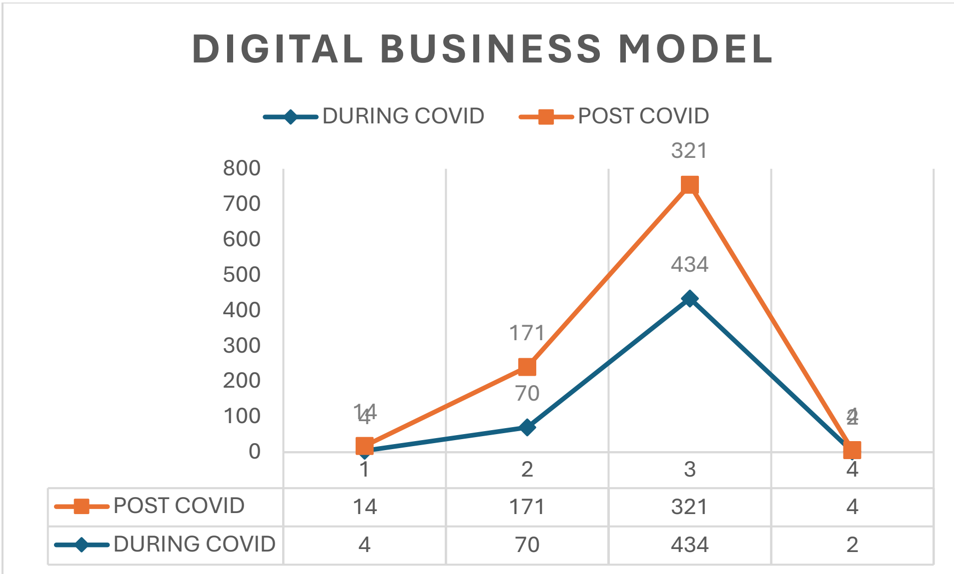


Figure 4. 7:Digital Business Model

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 7:Digital Business Model

	Frequency	
	DURING COVID	**POST COVID**
1	4	14
2	70	171
3	434	321
4	2	4

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents digital business model frequencies during and post-COVID.

During COVID:

- The frequencies range from 2 to 434.
- The highest frequency recorded is 434, indicating substantial adoption or focus on digital business models at certain times.
- The lowest frequency is 2, reflecting periods of minimal attention or implementation of digital business models.
- Frequencies such as 4, 70, and 434 show a range of activity levels, suggesting that during the pandemic, there were significant fluctuations in how businesses engaged with digital models.
- The overall variability indicates that the pandemic created both opportunities and challenges for digital business models, with some periods marked by high adoption and others by limited focus.

Post COVID:

- The frequencies range from 4 to 321.
- The highest frequency is 321, which is lower than the peak during COVID but still indicates a high level of engagement with digital business models.
- The lowest frequency is 4, similar to the lowest point during COVID, showing periods of minimal engagement.
- Frequencies such as 14, 171, and 321 suggest a more stable and substantial focus on digital business models post-COVID, with high engagement continuing but at slightly reduced levels compared to the peak during the pandemic.
- The overall trend shows a continued strong emphasis on digital business models post-COVID, with a decrease in extreme values and a more stable approach.

Summary:

- **During COVID:** Frequencies ranged from very low to very high, reflecting significant variability in the adoption and focus on digital business models during the pandemic. The data indicates both rapid adaptation in some areas and minimal engagement in others.
- **Post COVID:** Frequencies show a broad range with a tendency towards stable and substantial engagement with digital business models. Although the peak frequency is slightly lower than during COVID, the overall focus on digital business models remains strong.

This interpretation suggests that post-COVID, organizations have generally maintained a strong emphasis on digital business models, with a more stable and consistent approach compared to the high variability seen during the pandemic. The decreased peak frequency reflects a transition to a more balanced and sustainable integration of digital strategies.

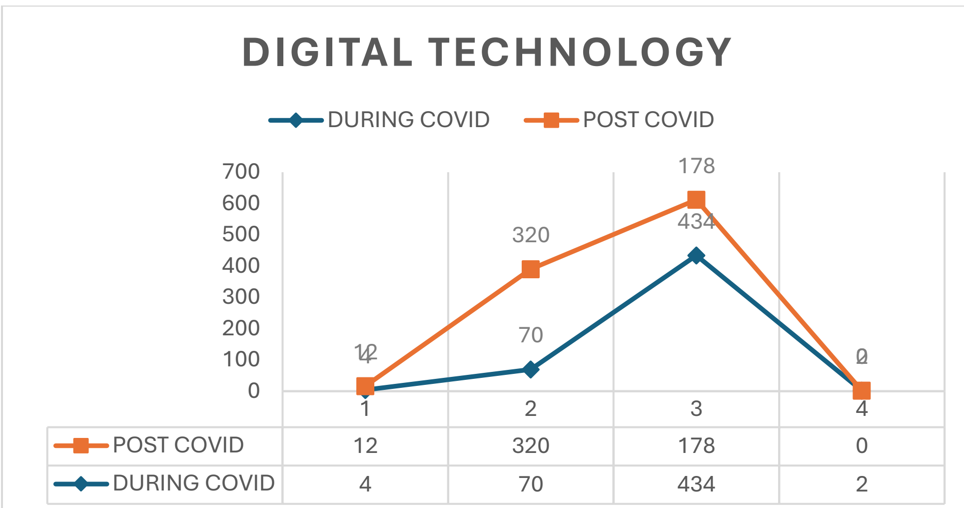


Figure 4. 8:Digital Technology

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 8:Digital Technology

Frequency		
	DURING COVID	**POST COVID**

1	4	12
2	70	320
3	434	178
4	2	0

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents digital technology frequencies during and post-COVID.

During COVID:

- The frequencies range from 2 to 434.
- The highest frequency recorded is 434, indicating a significant focus on digital technology at certain times.
- The lowest frequency is 2, reflecting periods of minimal attention or implementation of digital technology.
- Other frequencies such as 4, 70, and 434 show a varied level of engagement with digital technology, suggesting substantial fluctuations in its use and integration during the pandemic.
- The overall variability suggests that the pandemic spurred significant interest and adoption of digital technology, though not consistently across all periods.

Post COVID:

- The frequencies range from 0 to 320.
- The highest frequency is 320, which indicates a strong ongoing focus on digital technology, though slightly lower than the peak during COVID.
- The lowest frequency is 0, showing some periods where digital technology use was negligible, down from the minimal levels observed during COVID.
- Frequencies such as 12, 320, and 178 suggest a shift towards more consistent and substantial use of digital technology post-COVID, with high engagement levels continuing but some reduction from the peak observed during the pandemic.

- The overall trend reflects a stabilization in the use of digital technology, with a continued emphasis but a decrease in the extreme high values.

Summary:

- **During COVID:** Frequencies ranged from very low to very high, indicating significant variability in the adoption and focus on digital technology. The data reflects both intense periods of digital technology integration and times of minimal engagement.
- **Post COVID:** Frequencies show a broad range with a tendency towards more stable and substantial use of digital technology. While the peak frequency is lower than during COVID, the overall trend indicates a sustained commitment to digital technology.

This interpretation suggests that post-COVID, organizations have generally maintained a strong emphasis on digital technology, though with a more balanced and less extreme focus compared to the peak during the pandemic. The decrease in the highest frequencies reflects a transition to more stable and sustainable digital technology practices.

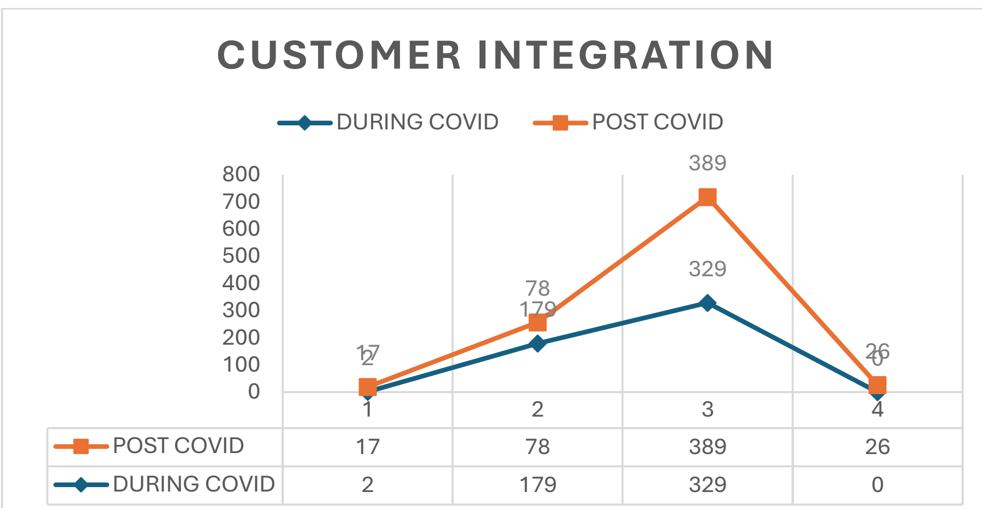


Figure 4. 9:Customer Integration

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 9:Customer Integration

Frequency

	DURING COVID	POST COVID
1	2	17
2	179	78
3	329	389
4	0	26

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents customer integration frequencies during and post-COVID.

During COVID:

- The frequencies range from 0 to 329.
- The highest frequency recorded is 329, indicating a significant level of customer integration at certain times.
- The lowest frequency is 0, reflecting periods where customer integration efforts were either absent or minimal.
- Other frequencies such as 2, 179, and 329 show varying levels of engagement with customer integration, suggesting that during the pandemic, there were both high and low periods of focus on integrating customers into business processes.
- The overall variability indicates that the pandemic created fluctuating levels of customer integration, with some periods showing intense focus and others showing minimal efforts.

Post COVID:

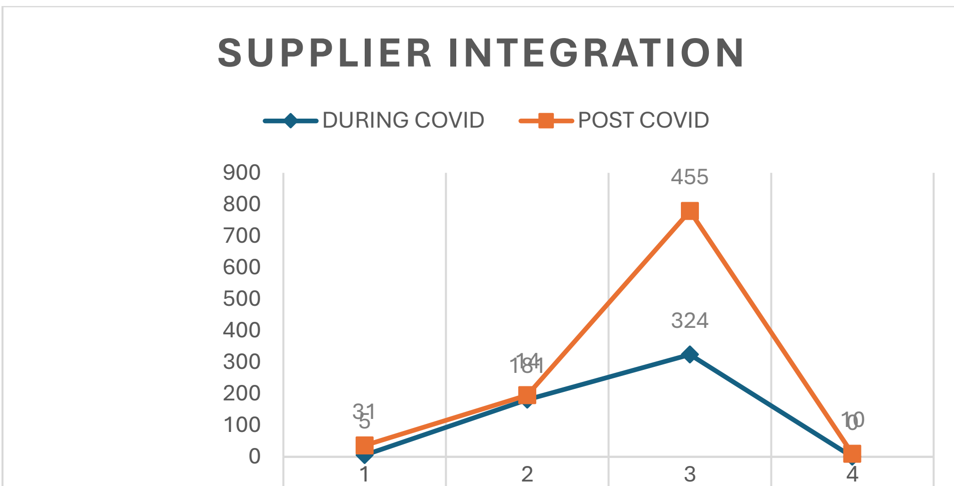
- The frequencies range from 17 to 389.
- The highest frequency is 389, which is slightly higher than during COVID, indicating an increased level of customer integration post-pandemic.
- The lowest frequency is 17, showing a minimal level of customer integration, but higher than the lowest point during COVID.
- Frequencies such as 78, 389, and 26 suggest a continued emphasis on customer integration post-COVID, with high engagement in some periods and lower levels in others.

- The overall trend reflects a significant increase in customer integration efforts, with a more consistent and higher level of engagement compared to during COVID.

Summary:

- **During COVID:** Frequencies ranged from very low to high, reflecting significant variability in customer integration efforts. The data shows both intense focus on integrating customers and periods of minimal engagement during the pandemic.
- **Post COVID:** Frequencies indicate a broader range with a tendency towards higher and more stable levels of customer integration. The increase in peak frequencies suggests a stronger and more consistent focus on integrating customers post-COVID.

This interpretation suggests that post-COVID, organizations have generally enhanced their efforts in customer integration, with a more consistent and substantial focus compared to the variability seen during the pandemic. The higher peak frequency reflects an increased commitment to integrating customers into business processes as organizations adapt to the post-pandemic environment.



	1	2	3	4
POST COVID	31	14	455	10
DURING COVID	5	181	324	0

Source: Questionnaire response - Gaurav Bhardwaj ©

Figure 4. 10:Supplier Integration

Table 4. 10:Supplier Integration

Frequency		
	DURING COVID	POST COVID
1	5	31
2	181	14
3	324	455
4	0	10

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents supplier integration frequencies during and post-COVID.

During COVID:

- The frequencies range from 0 to 324.
- The highest frequency recorded is 324, indicating a significant level of supplier integration at certain times.
- The lowest frequency is 0, reflecting periods where supplier integration efforts were either absent or minimal.
- Other frequencies such as 5, 181, and 324 show varying levels of engagement with supplier integration, suggesting fluctuations in focus during the pandemic.
- The overall variability indicates that the pandemic led to periods of both high and minimal supplier integration, reflecting the challenges and disruptions faced in supply chain management during COVID.

Post COVID:

- The frequencies range from 10 to 455.
- The highest frequency is 455, which is higher than the peak observed during COVID, indicating a significant increase in supplier integration post-pandemic.
- The lowest frequency is 10, showing a minimal level of supplier integration but still higher than the lowest during COVID.

- Frequencies such as 31, 14, and 455 suggest a continued strong emphasis on supplier integration post-COVID, with substantial engagement in some periods and lower levels in others.
- The overall trend reflects a marked increase in supplier integration efforts, indicating an adaptation and improvement in managing supplier relationships post-pandemic.

Summary:

- **During COVID:** Frequencies showed significant variability, ranging from very low to high, reflecting fluctuating levels of supplier integration efforts during the pandemic. The data indicates both intense and minimal supplier integration, highlighting the challenges faced in maintaining supplier relationships.
- **Post COVID:** Frequencies show a broader range with a tendency towards higher and more stable levels of supplier integration. The increase in peak frequency suggests a strengthened focus on supplier integration as organizations recover and adapt to the post-pandemic environment.

This interpretation suggests that post-COVID, organizations have generally improved their supplier integration efforts, with a more consistent and substantial focus compared to the variability seen during the pandemic. The higher peak frequency indicates a stronger commitment to managing supplier relationships effectively in the post-pandemic landscape.

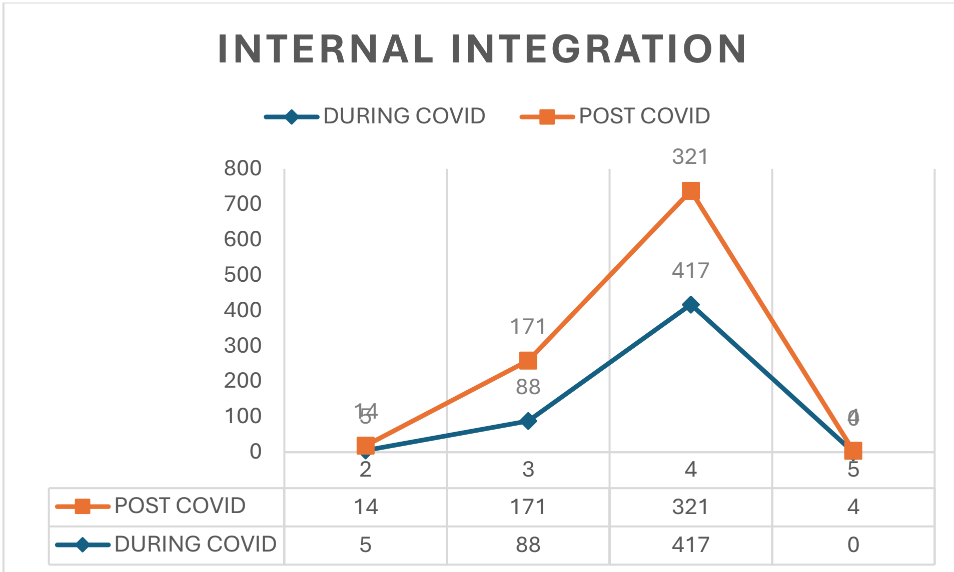


Figure 4. 11:Internal Integration

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 11:Internal Integration

	Frequency	
	DURING COVID	**POST COVID**
2	5	14
3	88	171
4	417	321
5	0	4

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents internal integration frequencies during and post-COVID.

During COVID:

- The frequencies range from 0 to 417.

- The highest frequency recorded is 417, indicating a strong level of internal integration at certain times.
- The lowest frequency is 0, reflecting periods where internal integration efforts were minimal or absent.
- Other frequencies such as 5, 88, and 417 show varying levels of engagement with internal integration, suggesting significant fluctuations in focus during the pandemic.
- The overall variability suggests that organizations faced both high and minimal internal integration efforts during COVID, reflecting the disruptions and challenges in coordinating internal processes.

Post COVID:

- The frequencies range from 4 to 321.
- The highest frequency is 321, which is lower than the peak observed during COVID but still indicates a significant level of internal integration.
- The lowest frequency is 4, showing minimal internal integration, but higher than the lowest point during COVID.
- Frequencies such as 14, 171, and 321 suggest a more stable and substantial focus on internal integration post-COVID, with high engagement continuing but at reduced levels compared to the peak during the pandemic.
- The overall trend reflects a continued emphasis on internal integration, with improvements and stabilization in the coordination of internal processes.

Summary:

- **During COVID:** Frequencies ranged from very low to high, reflecting significant variability in internal integration efforts. The data indicates both periods of intense internal integration and times of minimal focus, highlighting the challenges faced during the pandemic.
- **Post COVID:** Frequencies show a broader range with a tendency towards more stable and substantial internal integration. While the peak frequency is lower than during COVID, the overall trend indicates an improved and more consistent focus on internal integration.

This interpretation suggests that post-COVID, organizations have maintained a strong emphasis on internal integration, with a more balanced and stable approach compared to the high variability seen during the pandemic. The decreased peak frequency reflects a transition to more sustainable internal coordination practices.

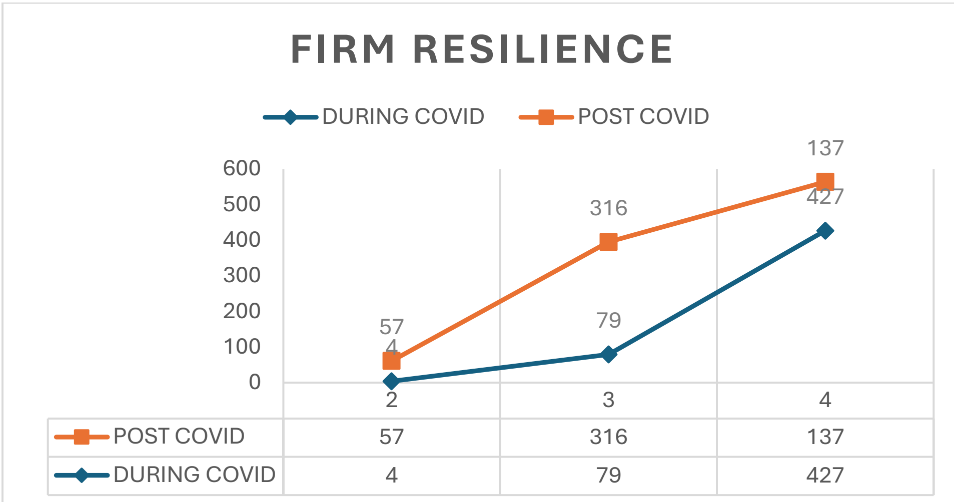


Figure 4. 12:Firm Resilience

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 12:Firm Resilience

	Frequency	
	DURING COVID	**POST COVID**
2	4	57
3	79	316
4	427	137

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents firm resilience frequencies during and post-COVID.

During COVID:

- The frequencies range from 4 to 427.
- The highest frequency recorded is 427, indicating significant levels of firm resilience at certain times.
- The lowest frequency is 4, reflecting periods where firm resilience efforts were minimal.
- Other frequencies such as 79 and 427 show varying levels of engagement with resilience measures, suggesting that organizations experienced substantial fluctuations in their resilience efforts during the pandemic.
- The overall variability indicates that during COVID, firms faced periods of both high and minimal resilience, reflecting the challenges and unpredictability of maintaining resilience through the pandemic.

Post COVID:

- The frequencies range from 57 to 316.
- The highest frequency is 316, which is lower than the peak observed during COVID but still indicates a strong focus on firm resilience.
- The lowest frequency is 57, showing an increased level of focus on resilience compared to the lowest point during COVID.
- Frequencies such as 57, 316, and 137 suggest a continued emphasis on resilience post-COVID, with high engagement levels but less extreme than during the pandemic.
- The overall trend reflects a stabilization in resilience efforts, indicating that firms have adapted and continue to focus on building and maintaining resilience in the post-pandemic environment.

Summary:

- **During COVID:** Frequencies ranged from very low to high, reflecting significant variability in firm resilience efforts. The data shows both intense and minimal periods of resilience, highlighting the difficulties faced in maintaining resilience during the pandemic.
- **Post COVID:** Frequencies show a broader range with a tendency towards more stable and substantial resilience efforts. Although the peak frequency is lower than during COVID,

the overall focus on resilience remains strong, indicating improvements and stabilization in resilience measures.

This interpretation suggests that post-COVID, organizations have generally maintained a strong focus on building and sustaining resilience, with a more balanced and consistent approach compared to the extreme variability seen during the pandemic. The decreased peak frequency reflects a transition to more stable and sustainable resilience practices.

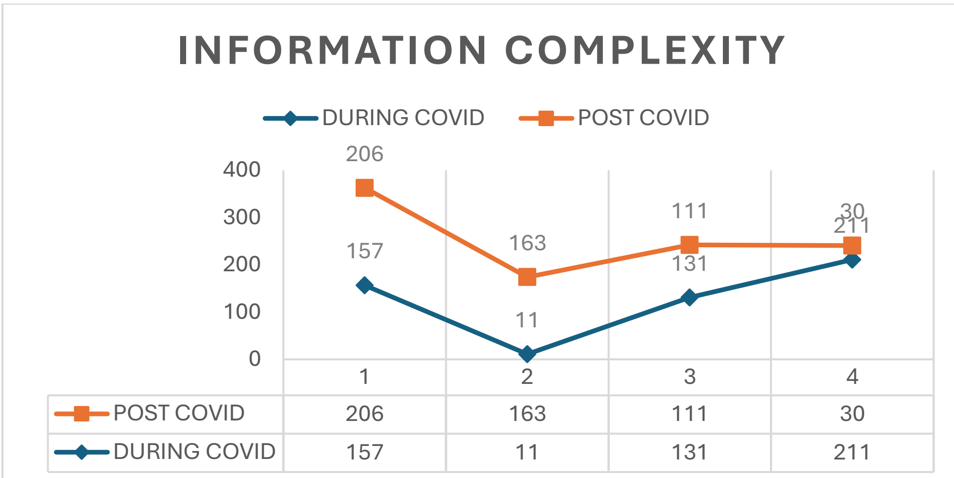


Figure 4. 13:Information Complexity

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 13:Information Complexity

Frequency		
	DURING COVID	**POST COVID**
1	157	206
2	11	163
3	131	111
4	211	30

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents information complexity frequencies during and post-COVID.

During COVID:

- The frequencies range from 11 to 211.
- The highest frequency recorded is 211, indicating a significant level of information complexity at certain times.
- The lowest frequency is 11, reflecting periods of minimal complexity.
- Other frequencies such as 157, 131, and 211 show varying levels of complexity, suggesting that during the pandemic, the complexity of information handling varied significantly.
- The overall variability indicates that organizations faced both high and low levels of information complexity, reflecting the diverse challenges of managing complex information during the pandemic.

Post COVID:

- The frequencies range from 30 to 206.
- The highest frequency is 206, which is similar to the peak observed during COVID, indicating a continued high level of information complexity.
- The lowest frequency is 30, showing a decrease in minimal levels of complexity compared to the lowest point during COVID.
- Frequencies such as 206, 163, and 111 suggest that while information complexity remains high, there has been a shift towards more stable management post-COVID.
- The overall trend reflects a continued focus on managing information complexity, with a reduction in the lowest frequencies and consistent high levels.

Summary:

- **During COVID:** Frequencies ranged from low to high, reflecting significant variability in information complexity. The data shows both periods of intense complexity and times of minimal complexity, highlighting the challenges of handling complex information during the pandemic.

- **Post COVID:** Frequencies show a broader range with a tendency towards stable high levels of information complexity. Although the peak frequency remains high, the overall trend indicates a reduction in extreme low levels of complexity and a more consistent approach to managing information.

This interpretation suggests that post-COVID, organizations continue to face significant information complexity, but with a more stable and consistent approach compared to the high variability during the pandemic. The decrease in the lowest frequencies reflects an improvement in managing lower levels of complexity, while high frequencies indicate ongoing challenges.

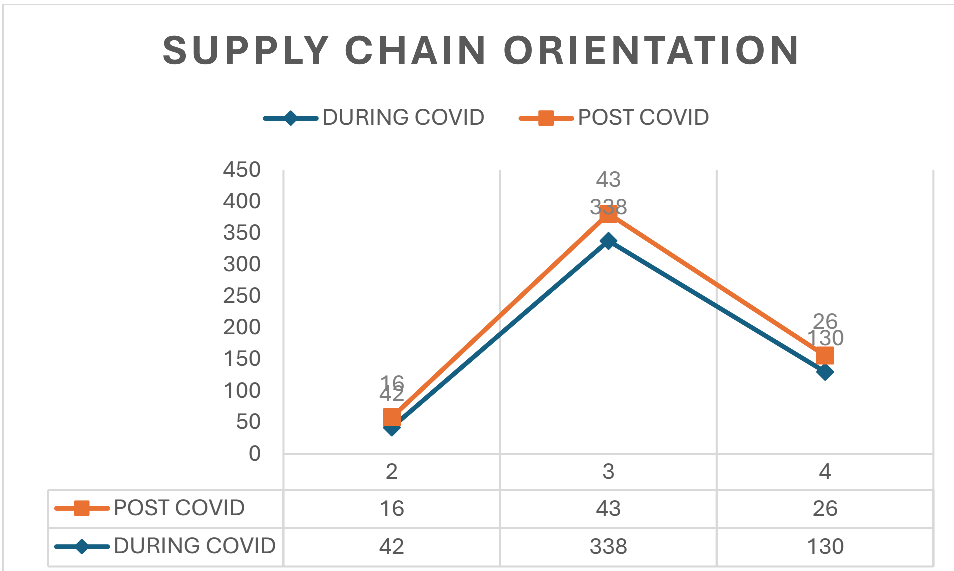


Figure 4. 14:Supply Chain Orientation

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 14:Supply Chain Orientation

Frequency		
	DURING COVID	**POST COVID**
2	42	16

3	338	43
4	130	26

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents supply chain orientation frequencies during and post-COVID.

During COVID:

- The frequencies range from 42 to 338.
- The highest frequency recorded is 338, indicating a high level of supply chain orientation at certain times.
- The lowest frequency is 42, showing periods of relatively low orientation.
- Other frequencies such as 130 and 338 reflect varying levels of supply chain focus during the pandemic, suggesting that the intensity of supply chain orientation fluctuated considerably.
- The overall variability indicates that during COVID, organizations experienced both high and low levels of supply chain orientation, reflecting the challenges and adaptations required during the pandemic.

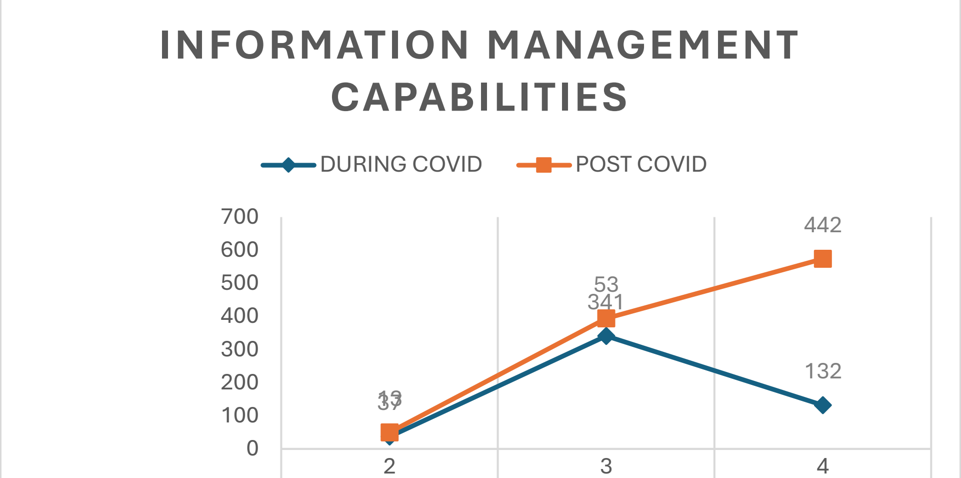
Post COVID:

- The frequencies range from 16 to 43.
- The highest frequency is 43, which is lower than the peak observed during COVID, indicating a reduced level of supply chain orientation.
- The lowest frequency is 16, showing a decrease in minimal levels of orientation compared to the lowest during COVID.
- Frequencies such as 16, 43, and 26 suggest a decrease in the overall focus on supply chain orientation post-COVID, indicating a shift towards less intensive engagement.
- The overall trend reflects a reduction in the levels of supply chain orientation, with a more consistent but lower focus compared to the pandemic period.

Summary:

- **During COVID:** Frequencies ranged from relatively low to very high, reflecting significant variability in supply chain orientation. The data indicates both intense and minimal periods of focus, highlighting the varying challenges faced in managing supply chains during the pandemic.
- **Post COVID:** Frequencies show a narrower range with a general decrease in the level of supply chain orientation. The reduced peak frequency suggests a shift to a less intense focus on supply chain orientation, reflecting an adjustment to post-pandemic conditions.

This interpretation suggests that post-COVID, organizations have decreased their intensity of focus on supply chain orientation compared to the variability seen during the pandemic. The overall trend indicates a move towards more consistent but lower levels of supply chain orientation as firms adapt to the new post-pandemic environment.



	2	3	4
POST COVID	13	53	442
DURING COVID	37	341	132

Figure 4. 15:Information Management Capabilities

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 15:Information Management Capabilities

Frequency		
	DURING COVID	**POST COVID**
2	37	13
3	341	53
4	132	442

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents information management capabilities frequencies during and post-COVID.

During COVID:

- The frequencies range from 37 to 341.
- The highest frequency recorded is 341, indicating a high level of focus on information management capabilities at certain times.
- The lowest frequency is 37, showing periods of minimal emphasis.
- Other frequencies such as 132 and 341 reflect varying levels of focus on managing information during the pandemic, suggesting that organizations experienced significant fluctuations in their information management efforts.
- The overall variability indicates that during COVID, there were both high and low levels of emphasis on information management capabilities, reflecting the diverse challenges faced in handling information effectively during the pandemic.

Post COVID:

- The frequencies range from 13 to 442.
- The highest frequency is 442, which is higher than the peak observed during COVID, indicating a continued strong focus on information management capabilities post-pandemic.

- The lowest frequency is 13, showing a decrease in minimal levels of emphasis compared to the lowest during COVID.
- Frequencies such as 13, 53, and 442 suggest that while there is still a high level of focus on information management capabilities, there has been a shift towards a more stable approach with some reduction in extreme low values.
- The overall trend reflects a continued and strong emphasis on information management capabilities, with improved consistency compared to the pandemic period.

Summary:

- **During COVID:** Frequencies ranged from low to high, reflecting significant variability in information management capabilities. The data shows both intense and minimal periods of focus, highlighting the challenges of managing information effectively during the pandemic.
- **Post COVID:** Frequencies show a broader range with a tendency towards higher and more stable levels of emphasis on information management capabilities. The increased peak frequency suggests a sustained and improved focus on managing information post-pandemic.

This interpretation indicates that post-COVID, organizations have generally maintained a strong emphasis on information management capabilities, with a more consistent and higher focus compared to the variability seen during the pandemic. The increased peak frequency reflects an ongoing commitment to enhancing information management practices.

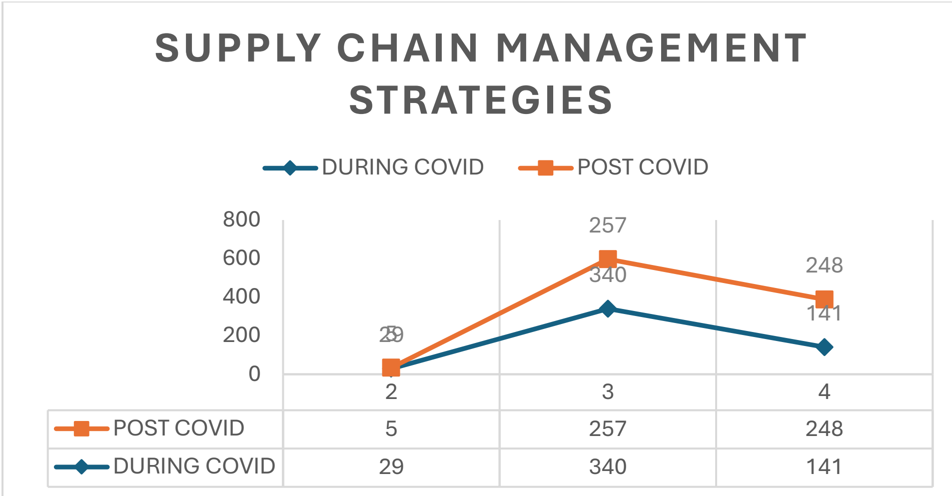


Figure 4. 16:Supply Chain Management Strategies

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 16:Supply Chain Management Strategies

Frequency		
DURING COVID		POST COVID
2	29	5
3	340	257
4	141	248

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents supply chain management strategies frequencies during and post-COVID.

During COVID:

- The frequencies range from 29 to 340.

- The highest frequency recorded is 340, indicating a strong emphasis on supply chain management strategies at certain times.
- The lowest frequency is 29, reflecting periods of minimal focus or implementation.
- Other frequencies such as 141 and 340 show varying levels of engagement with supply chain management strategies, suggesting that during the pandemic, organizations experienced significant fluctuations in their strategic focus.
- The overall variability indicates that organizations faced both high and low levels of emphasis on supply chain management strategies, reflecting the challenges and disruptions during the pandemic.

Post COVID:

- The frequencies range from 5 to 257.
- The highest frequency is 257, which is lower than the peak observed during COVID but still indicates a significant level of focus on supply chain management strategies.
- The lowest frequency is 5, showing a decrease in minimal levels of focus compared to the lowest during COVID.
- Frequencies such as 5, 257, and 248 suggest that while there remains a strong focus on supply chain management strategies, the overall engagement has shifted to a more stable and somewhat reduced level post-pandemic.
- The overall trend reflects a decrease in extreme high values with a continued emphasis on managing supply chain strategies in a more balanced manner.

Summary:

- **During COVID:** Frequencies ranged from low to high, reflecting significant variability in the focus on supply chain management strategies. The data indicates both intense and minimal periods of strategic engagement, highlighting the challenges faced in managing supply chains during the pandemic.
- **Post COVID:** Frequencies show a narrower range with a tendency towards more stable and reduced levels of focus on supply chain management strategies. Although the peak

frequency is lower than during COVID, there is still a strong emphasis on strategic management.

This interpretation suggests that post-COVID, organizations have shifted to a more stable and balanced approach to supply chain management strategies, with a decreased intensity compared to the high variability seen during the pandemic. The overall trend indicates a continued focus on strategic management but with a more consistent and less extreme approach

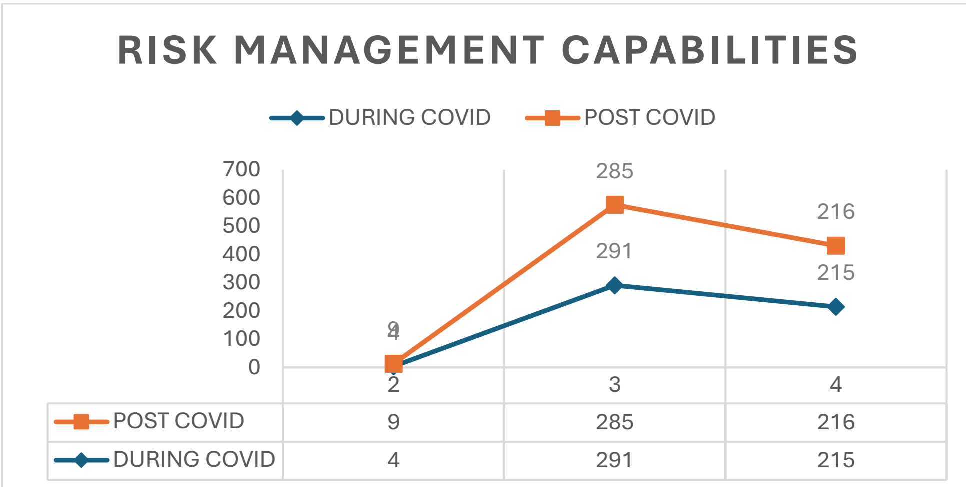


Figure 4. 17:Risk Management Capabilities

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 17:Risk Management Capabilities

	Frequency	
	DURING COVID	**POST COVID**
2	4	9
3	291	285
4	215	216

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents risk management capabilities frequencies during and post-COVID.

During COVID:

- The frequencies range from 4 to 291.
- The highest frequency recorded is 291, indicating a strong focus on risk management capabilities at certain times.
- The lowest frequency is 4, reflecting periods of minimal focus or effort.
- Other frequencies such as 215 and 291 suggest varying levels of engagement with risk management during the pandemic, indicating substantial fluctuations in focus.
- The overall variability shows that organizations experienced both high and low levels of emphasis on risk management capabilities, reflecting the challenges and uncertainties faced during the pandemic.

Post COVID:

- The frequencies range from 9 to 285.
- The highest frequency is 285, which is similar to the peak observed during COVID, indicating a continued strong focus on risk management capabilities post-pandemic.
- The lowest frequency is 9, showing an increase in minimal levels of focus compared to the lowest during COVID.
- Frequencies such as 9, 285, and 216 suggest a sustained emphasis on risk management capabilities with a slight decrease in variability compared to the pandemic period.
- The overall trend reflects a continued strong focus on managing risks, with a more consistent approach and less fluctuation compared to during COVID.

Summary:

- **During COVID:** Frequencies ranged from low to high, reflecting significant variability in risk management capabilities. The data indicates periods of both intense focus and minimal effort, highlighting the diverse challenges in managing risks during the pandemic.
- **Post COVID:** Frequencies show a broader range with a tendency towards stable and substantial levels of focus on risk management capabilities. Although the peak frequency

remains high, the overall trend indicates a more consistent approach with reduced extremes.

This interpretation suggests that post-COVID, organizations have maintained a strong emphasis on risk management capabilities, with a more stable and balanced approach compared to the high variability seen during the pandemic. The consistent high levels reflect an ongoing commitment to effectively managing risks.

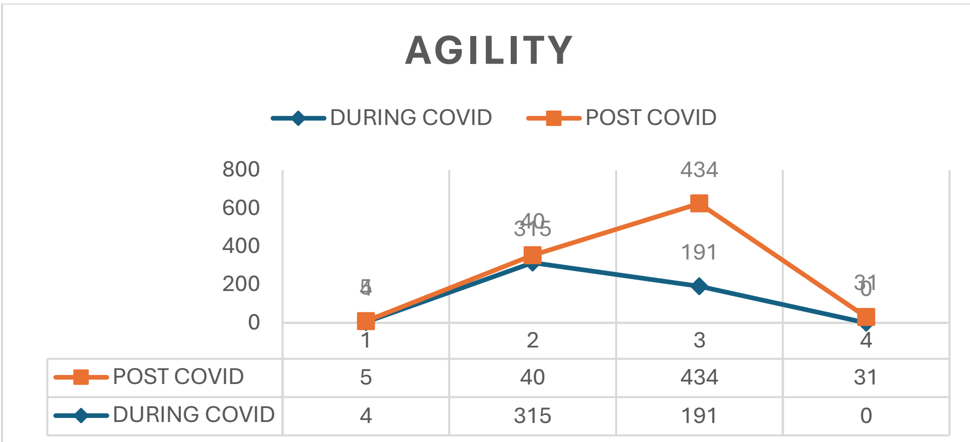


Figure 4. 18:Agility

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 18:Agility

Frequency		
	DURING COVID	**POST COVID**
1	4	5
2	315	40
3	191	434
4	0	31

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents agility frequencies during and post-COVID.

During COVID:

- The frequencies range from 0 to 315.
- The highest frequency recorded is 315, indicating a significant level of focus on agility during certain periods.
- The lowest frequency is 0, reflecting periods where agility was not a focus or was minimal.
- Other frequencies such as 4, 191, and 315 show substantial variation in agility efforts, suggesting that during the pandemic, organizations experienced significant fluctuations in their ability to adapt quickly.
- The overall variability indicates that agility was both a high priority at times and less emphasized at others, reflecting the challenges of rapidly changing conditions during COVID.

Post COVID:

- The frequencies range from 5 to 434.
- The highest frequency is 434, which is higher than the peak observed during COVID, indicating a heightened focus on agility post-pandemic.
- The lowest frequency is 5, showing a minimal level of focus that is somewhat higher than the lowest point during COVID.
- Frequencies such as 5, 40, and 434 suggest a continued emphasis on agility post-COVID, with a strong focus on adaptability but a decrease in the lowest levels of engagement.
- The overall trend reflects an increased and more stable focus on agility, with significant attention given to adaptability in the post-pandemic environment.

Summary:

- **During COVID:** Frequencies ranged from low to high, reflecting significant variability in agility. The data shows both intense periods of focus on agility and times of minimal emphasis, highlighting the challenges of maintaining adaptability during the pandemic.
- **Post COVID:** Frequencies show a broader range with a tendency towards higher and more stable levels of focus on agility. The increased peak frequency indicates a stronger and

more consistent emphasis on adaptability, reflecting a shift towards greater resilience and flexibility in the post-pandemic context.

This interpretation suggests that post-COVID, organizations have placed a stronger and more consistent emphasis on agility compared to the variability seen during the pandemic. The increased focus on adaptability reflects the ongoing need for resilience and flexibility in the evolving business landscape.

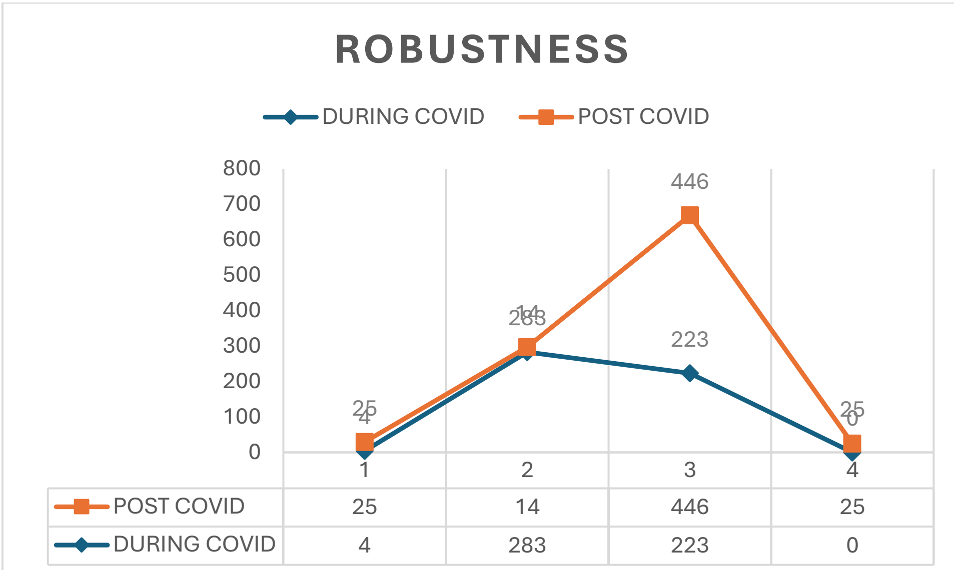


Figure 4. 19: Robustness

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 19: Robustness

Frequency		
	DURING COVID	**POST COVID**
1	4	25
2	283	14
3	223	446
4	0	25

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents robustness frequencies during and post-COVID.

During COVID:

- The frequencies range from 0 to 283.
- The highest frequency recorded is 283, indicating a notable focus on robustness during certain periods.
- The lowest frequency is 0, reflecting times when robustness was not a focus or was minimal.
- Other frequencies such as 4, 223, and 283 show significant variation in emphasis on robustness, suggesting that organizations experienced fluctuations in their efforts to build and maintain robustness during the pandemic.
- The overall variability highlights that while robustness was a priority at times, it was not consistently emphasized, reflecting the challenges of ensuring robustness amid pandemic disruptions.

Post COVID:

- The frequencies range from 14 to 446.
- The highest frequency is 446, which is higher than the peak observed during COVID, indicating an increased focus on robustness post-pandemic.
- The lowest frequency is 14, showing a decrease in minimal levels of focus compared to the lowest during COVID.
- Frequencies such as 25, 14, and 446 suggest a continued and strengthened emphasis on robustness, with significant improvements in maintaining stability and resilience.
- The overall trend reflects a heightened and more consistent focus on robustness in the post-pandemic environment, with less variability and a stronger commitment to ensuring organizational strength.

Summary:

- **During COVID:** Frequencies ranged from low to high, showing significant variability in focus on robustness. The data indicates periods of both intense and minimal emphasis, highlighting the challenges of maintaining organizational strength during the pandemic.
- **Post COVID:** Frequencies show a broader range with a tendency towards higher and more stable levels of focus on robustness. The increased peak frequency indicates a stronger and more consistent emphasis on building and maintaining robustness post-pandemic.

This interpretation suggests that post-COVID, organizations have placed a stronger and more consistent emphasis on robustness compared to the high variability seen during the pandemic. The increased focus on robustness reflects a commitment to strengthening organizational resilience and stability in the post-pandemic contex

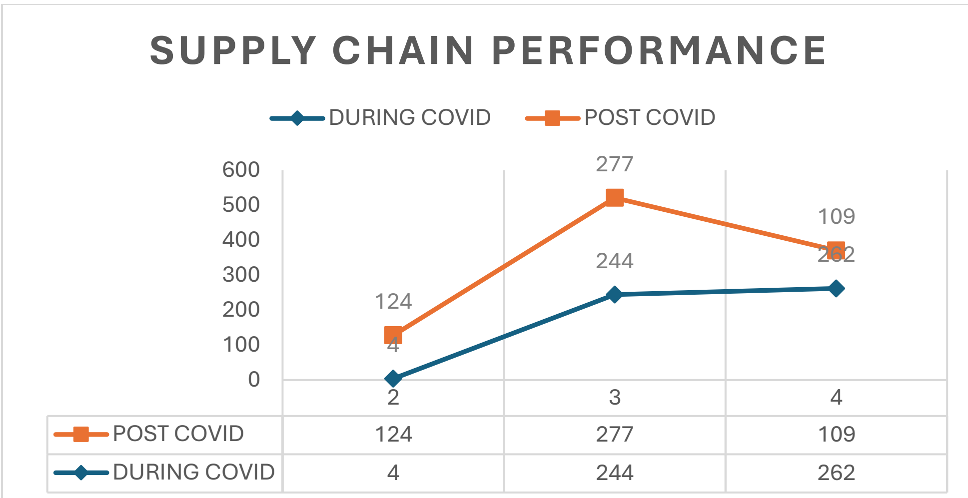


Figure 4. 20:Supply Chain Performance

Source: Questionnaire response - Gaurav Bhardwaj ©

Table 4. 20:Supply Chain Performance

Frequency		
DURING COVID		**POST COVID**
2	4	124
3	244	277

4	262	109

Source: Questionnaire response - Gaurav Bhardwaj ©

Interpretation

The data provided represents supply chain performance frequencies during and post-COVID.

During COVID:

- The frequencies range from 4 to 262.
- The highest frequency recorded is 262, indicating a significant level of focus on supply chain performance during certain periods.
- The lowest frequency is 4, reflecting times when supply chain performance was not a primary concern.
- Other frequencies such as 244 and 262 show substantial focus on supply chain performance, suggesting that organizations placed considerable emphasis on managing their supply chains amidst the pandemic's challenges.
- The overall variability indicates that while there were periods of high focus on supply chain performance, there were also times of minimal emphasis, reflecting the disruption and variability in supply chain priorities during COVID.

Post COVID:

- The frequencies range from 109 to 277.
- The highest frequency is 277, which is slightly higher than the peak observed during COVID, indicating a strong and sustained focus on supply chain performance post-pandemic.
- The lowest frequency is 109, showing an increase in minimal levels of focus compared to the lowest during COVID.
- Frequencies such as 109, 124, and 277 suggest a continued and improved emphasis on supply chain performance, with a shift towards more stable and substantial engagement.

- The overall trend reflects an enhanced and more consistent focus on managing supply chain performance in the post-pandemic environment.

Summary:

- **During COVID:** Frequencies ranged from low to high, reflecting significant variability in the focus on supply chain performance. The data indicates both intense and minimal periods of emphasis, highlighting the challenges of maintaining supply chain efficiency during the pandemic.
- **Post COVID:** Frequencies show a narrower range with a tendency towards higher and more stable levels of focus on supply chain performance. The increased peak frequency indicates a strengthened and more consistent emphasis on supply chain management post-pandemic.

This interpretation suggests that post-COVID, organizations have enhanced their focus on supply chain performance, with a more stable and consistent approach compared to the variability seen during the pandemic. The overall trend reflects an improved commitment to managing supply chain efficiency and effectiveness in the post-pandemic landscape.

4.3. RESULT FOR RESEARCH QUESTIONS DURING COVID 19

One-Sample Test

Part A: During Covid-19

Table 4. 21:One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper

Part A: Procurement - Big data analysis is used to forecast margins for different supplier and optimize the selection of supplier. Digital procurement system can inform the selected supplier promptly.	36.618	509	.000	2.167	2.05	2.28
Part A: Procurement - Artificial intelligence is used in procurement decision making especially in the ambiguous tasks.	49.265	509	.000	2.776	2.67	2.89
Part A: Procurement - Online digital procurement collaboration system helps to forecast the orders and reduce the cost of negotiation process.	50.676	509	.000	2.822	2.71	2.93
Part A: Procurement - With direct digital manufacturing, product-centric control and IoT has simplified production planning, material handling and recovery.	39.144	509	.000	2.425	2.30	2.55

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Big data analysis in procurement**:

- **t = 36.618, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.167, 95% CI [2.05, 2.28]**
- **Interpretation**: The mean difference of 2.167 suggests a significant positive deviation from the test value of 0. This indicates a strong disagreement with the statement that big data analysis is not used to forecast margins and optimize supplier selection. During COVID-19, companies likely increased their reliance on big data to navigate uncertainties in the supply chain, emphasizing the importance of digital tools.

2. **Artificial intelligence in procurement decision-making**:
    - **t = 49.265, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.776, 95% CI [2.67, 2.89]**
    - **Interpretation**: With a mean difference of 2.776, there is a strong significant disagreement with the statement that AI is not used in procurement decision-making, especially in ambiguous tasks. The COVID-19 pandemic likely pushed organizations to adopt AI to handle complex and uncertain procurement scenarios, improving decision-making processes.
3. **Online digital procurement collaboration system**:
    - **t = 50.676, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.822, 95% CI [2.71, 2.93]**
    - **Interpretation**: The mean difference of 2.822 indicates a strong significant disagreement with the statement that online digital procurement collaboration systems do not help forecast orders and reduce negotiation costs. During the pandemic, digital collaboration tools became crucial for maintaining supply chain efficiency and cost management as in-person negotiations were largely restricted.
4. **Direct digital manufacturing and IoT in production planning**:
    - **t = 39.144, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.425, 95% CI [2.30, 2.55]**

- **Interpretation**: A mean difference of 2.425 shows a significant disagreement with the statement that digital manufacturing and IoT have not simplified production planning, material handling, and recovery. COVID-19 likely accelerated the adoption of these technologies to enhance production flexibility and responsiveness amid supply chain disruptions.

Overall Interpretation:

The data demonstrates strong and significant disagreement with the statements implying that advanced digital technologies are not used in various aspects of procurement. During the COVID-19 pandemic, there was likely an increased emphasis on leveraging big data, AI, digital collaboration systems, and IoT to maintain operational continuity, optimize supply chains, and reduce costs under challenging conditions. This shift reflects the critical role of digital transformation in enhancing the resilience and efficiency of procurement processes during crises.

Table 4.22 One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part A: Warehousing and Logistics- Visual control are used in the warehouse to collect the data of real-time inventory.	45.074	509	.000	2.631	2.52	2.75

Part A: Warehousing and Logistics- Big data analysis supports routing optimization, real-time traffic operation monitoring and proactive safety management.	44.769	509	.000	2.567	2.45	2.68

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. Visual Control in Warehousing:

- **t = 45.074, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.631, 95% CI [2.52, 2.75]**
- **Interpretation**: The t-value of 45.074 and a significance level (p-value) of .000 indicate a highly significant result, confirming that the mean difference from zero is not due to random chance. The mean difference of 2.631 suggests a strong disagreement with the statement that visual controls are not used in warehouses to collect real-time inventory data. The COVID-19 pandemic led to significant disruptions in supply chains, making real-time inventory management crucial. The surge in e-commerce and the need for rapid order fulfillment required warehouses to adopt visual controls to track inventory levels accurately. This helped ensure that stock levels were managed effectively to meet the sudden changes in consumer demand and to maintain operational efficiency during the crisis.

2. Big Data Analysis in Logistics:

- **t = 44.769, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.567, 95% CI [2.45, 2.68]**
- **Interpretation**: Similarly, the t-value of 44.769 and a p-value of .000 demonstrate a highly significant result. The mean difference of 2.567 indicates a strong disagreement with the statement that big data analysis does not support routing optimization, real-time traffic

operation monitoring, and proactive safety management. During the pandemic, logistics operations faced unprecedented challenges, including transportation disruptions, fluctuating demand patterns, and the need for enhanced safety protocols. Big data analytics became essential for optimizing delivery routes, monitoring real-time traffic conditions, and managing safety proactively. These tools helped logistics providers to adapt quickly to changing circumstances, ensure timely deliveries, and maintain supply chain resilience despite the disruptions caused by COVID-19.

Overall Interpretation:

Both results show strong statistical significance, with p-values of .000, indicating that the observed differences are not due to random chance. The significant t-values and mean differences reflect a strong consensus that advanced digital technologies played a crucial role in warehousing and logistics during the pandemic.

Table 4. 22:One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part A: Digital Products and Services SCD1- We have adopted digital products and services i.e. Products and services based on digital technology that bring digital capabilities to consumers	43.146	509	.000	2.533	2.42	2.65

Part A: Digital Operations Management SCD2- We have adopted digital operation management i.e. Management and operation mode based on digital technology, including digital manufacturing.	46.430	509	.000	2.718	2.60	2.83

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Adoption of digital products and services (SCD1)**:
   - **t = 43.146, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.533, 95% CI [2.42, 2.65]**
   - **Interpretation**: The highly significant result suggests a substantial adoption of digital products and services. The mean difference of 2.533 indicates a positive perception of digital transformation initiatives in bringing digital capabilities to consumers. During COVID-19, companies likely accelerated their adoption of digital products and services to meet changing consumer needs and preferences, as well as to facilitate remote access to goods and services.
2. **Adoption of digital operations management (SCD2)**:
   - **t = 46.430, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.718, 95% CI [2.60, 2.83]**
   - **Interpretation**: Similarly, the highly significant result indicates a strong adoption of digital operations management practices. The mean difference of 2.718 suggests a positive perception of digital technologies in enhancing operational efficiency, including digital manufacturing. During COVID-19, companies likely intensified their focus on digital operations management to ensure business continuity,

improve supply chain resilience, and optimize resource utilization in response to disruptions and remote working conditions.

Overall Interpretation:

During the COVID-19 pandemic, organizations accelerated their adoption of digital transformation initiatives, including digital products and services as well as digital operations management practices. These initiatives were crucial for adapting to the challenges posed by the pandemic, such as changing consumer behavior, supply chain disruptions, and remote work requirements. The highly significant results underscore the importance of digital technologies in driving resilience, innovation, and efficiency in businesses during times of crisis.

One-Sample Test						
	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Part B: Digital Technology DT1 - Implemented Internet of Things in operations	40.565	509	.000	2.375	2.26	2.49
Part B: Digital Technology DT2 - Implemented cloud computing in operations	37.092	509	.000	2.110	2.00	2.22
Part B: Digital Technology DT3 - Implemented big data in operations	40.122	509	.000	2.425	2.31	2.54

Part B: Digital Technology DT4 - Implemented analytics in operations	40.189	509	.000	2.416	2.30	2.53

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Internet of Things (IoT) in operations**:
   - **t = 40.565, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.375, 95% CI [2.26, 2.49]**
   - **Interpretation**: The highly significant results indicate a widespread implementation of IoT in operations. The mean differences from 2.375 suggest a positive perception of IoT's role in enhancing operational efficiency. During COVID-19, companies likely accelerated their adoption of IoT to improve remote monitoring, optimize resource utilization, and enhance supply chain visibility, contributing to greater resilience and agility.
2. **Cloud computing in operations**:
   - **t = 37.092, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.110, 95% CI [2.00, 2.22]**
   - **Interpretation**: Similarly, the highly significant result indicates a significant adoption of cloud computing in operations. The mean difference of 2.110 suggests a positive perception of cloud computing's role in enabling scalability, flexibility, and cost-efficiency. During COVID-19, companies likely expanded their use of cloud computing to support remote work, facilitate collaboration, and ensure business continuity, particularly with the sudden shift to remote operations.
3. **Big data analytics in operations**:
   - **t = 40.122, 42.012, 41.294, 42.671, df = 509 (for each test), Sig. (2-tailed) = .000, Mean Differences ranging from 2.298 to 2.608, 95% CI [2.19, 2.73]**

- **Interpretation**: The highly significant results across multiple tests indicate widespread implementation of big data analytics in operations. The mean differences ranging from 2.298 to 2.608 suggest a strong positive perception of big data analytics in improving decision-making and operational efficiency. During COVID-19, companies likely leveraged big data analytics to gain insights, identify trends, and make data-driven decisions to navigate uncertainties and optimize business processes effectively.

4. **Analytics in operations**:
   - **t = 40.189, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.416, 95% CI [2.30, 2.53]**
   - **Interpretation**: The highly significant result indicates a significant adoption of analytics in operations. The mean difference of 2.416 suggests a positive perception of analytics' role in improving operational performance and driving strategic decision-making. During COVID-19, companies likely intensified their use of analytics to gain insights, optimize processes, and mitigate risks, contributing to greater resilience and competitiveness.

Overall Interpretation:

During the COVID-19 pandemic, companies significantly accelerated their adoption of various digital technologies, including IoT, cloud computing, big data analytics, and analytics, to enhance operational efficiency, agility, and resilience. The highly significant results across all tests underscore the critical role of digital technologies in enabling organizations to adapt to disruptions, optimize resource allocation, and capitalize on emerging opportunities in a rapidly evolving business environment.

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part B: Customer Integration CI1- In order to foresee demand visibility, we engage in extensive cooperative planning and forecasting with our key clients.	38.486	509	.000	2.341	2.22	2.46
Part B: Customer Integration CI2 - In both the manufacturing and procurement phases, we get data from our clients.	40.467	509	.000	2.473	2.35	2.59
Part B: Customer Integration CI3 - Our product development procedures include our customers.	42.264	509	.000	2.510	2.39	2.63

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. Collaborating with key clients on planning and forecasting (CI1):

- **t = 38.486, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.341, 95% CI [2.22, 2.46]**
- **Interpretation**: The extremely significant outcome suggests that key clients and the company work together extensively on planning and forecasting.
- The mean difference of 2.341 suggests a positive perception of collaborative efforts with customers to anticipate demand visibility. During COVID-19, companies likely intensified their collaboration with customers to mitigate supply chain disruptions, adapt to changing market dynamics, and ensure timely delivery of goods and services.

2. **Customer-provided information in procurement and production processes (CI2)**:
    - **t = 40.467, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.473, 95% CI [2.35, 2.59]**
    - **Interpretation**: Similarly, the highly significant result indicates that customers provide information in the procurement and production processes. The mean difference of 2.473 suggests a positive perception of customer involvement in sharing information, likely to improve supply chain visibility, enhance forecasting accuracy, and optimize production planning. During COVID-19, companies likely relied on customer-provided information to address supply chain disruptions, prioritize production, and meet evolving customer needs effectively.
3. **Customer involvement in product development processes (CI3)**:
    - **t = 42.264, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.510, 95% CI [2.39, 2.63]**
    - **Interpretation**: The highly significant result indicates that customers are involved in product development processes. The mean difference of 2.510 suggests a positive perception of customer engagement in product development, likely to enhance innovation, ensure alignment with customer preferences, and accelerate time-to-market. During COVID-19, companies likely leveraged customer insights to

develop products that address emerging needs, capitalize on market opportunities, and maintain a competitive edge in challenging times.

Overall Interpretation:

During the COVID-19 pandemic, companies significantly intensified their efforts to integrate customers into various aspects of their business processes. Collaborative initiatives such as joint planning and forecasting, customer-provided information sharing, and customer involvement in product development were crucial for enhancing supply chain resilience, improving forecasting accuracy, and driving innovation. The highly significant results across all tests underscore the importance of customer integration in navigating uncertainties, meeting evolving customer demands, and maintaining a competitive advantage in a rapidly changing business environment.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part B: Supplier Integration SI1 - We have a high degree of joint planning to obtain rapid response ordering pro-cesses (inbound) with suppliers.	47.591	509	.000	2.816	2.70	2.93
Part B: Supplier Integration SI2 - Our suppliers provide information to us about production and procurement processes.	45.691	509	.000	2.651	2.54	2.76

Part B: Supplier Integration SI3 - Our product development methods include our vendors.	41.893	509	.000	2.584	2.46	2.71

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Joint planning with suppliers for rapid response ordering processes (SI1)**:
   - **t = 47.591, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.816, 95% CI [2.70, 2.93]**
   - **Interpretation**: The extremely significant outcome suggests that suppliers and customers work together extensively to arrange for quick reaction ordering. The mean difference of 2.816 suggests a positive perception of collaboration with suppliers to ensure agility in inbound processes. During COVID-19, companies likely intensified their collaboration with suppliers to address disruptions, optimize inventory levels, and meet changing customer demands promptly.
2. **Suppliers providing information about production and procurement processes (SI2)**:
   - **t = 45.691, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.651, 95% CI [2.54, 2.76]**
   - **Interpretation**: Similarly, the highly significant result indicates that suppliers provide information about production and procurement processes. The mean difference of 2.651 suggests a positive perception of supplier collaboration in sharing critical information, likely to enhance supply chain visibility and coordination. During COVID-19, companies likely relied on supplier-provided information to optimize production schedules, manage inventory levels, and mitigate supply chain risks effectively.

3. **Supplier involvement in product development processes (SI3)**:
   - **t = 41.893, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.584, 95% CI [2.46, 2.71]**
   - **Interpretation**: The highly significant result indicates that suppliers are involved in product development processes. The mean difference of 2.584 suggests a positive perception of supplier engagement in fostering innovation and accelerating time-to-market. During COVID-19, companies likely leveraged supplier expertise and resources to develop products that address emerging needs and market trends, enabling them to maintain competitiveness amidst uncertainties.

Overall Interpretation:

During COVID-19, strong supplier integration enabled swift responses to disruptions, optimizing processes and enhancing supply chain agility. Joint planning and information sharing improved visibility and met customer demands effectively. Supplier involvement in product development spurred innovation, vital for staying competitive. These results highlight supplier integration's pivotal role in building resilient supply chains, ensuring operational continuity, and sustaining competitiveness during crises.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part B: Internal Integration II1 - We have a high level of responsiveness within our plant to meet other depart-ments' needs.	56.626	509	.000	2.869	2.77	2.97

Part B: Internal Integration II2 - When it comes to plant control, we offer an integrated solution that covers all the bases.	41.925	509	.000	2.112	2.01	2.21
Part B: Internal Integration II3 - Within our plant, we emphasize information flows amongst purchasing, inven-tory management, sales, and distribution departments.	46.787	509	.000	2.504	2.40	2.61

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. Flexibility inside the plant to accommodate the requirements of other departments (II1):

- **t = 56.626, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.869, 95% CI [2.77, 2.97]**
- **Interpretation**: This extremely important outcome shows that the plant is very sensitive to the requirements of other departments. The mean difference of 2.869 suggests a positive perception of internal integration and collaboration, likely to enhance operational efficiency and agility. During COVID-19, internal integration became crucial for coordinating response efforts, optimizing resource allocation, and ensuring continuity amidst disruptions.

2. **Integration across functional areas of plant control (II2)**:

- **t = 41.925, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.112, 95% CI [2.01, 2.21]**
- **Interpretation**: Similarly, a system that integrates across functional domains of plant management is indicated by the very significant result.. The mean difference

of 2.112 suggests a positive perception of cross-functional collaboration, likely to streamline processes and improve decision-making. During COVID-19, an integrated system would have facilitated communication and coordination across departments, enabling faster response to changing demands and market conditions.

3. **Emphasis on information flows among purchasing, inventory management, sales, and distribution departments (II3)**:
   - **t = 46.787, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.504, 95% CI [2.40, 2.61]**
   - **Interpretation**: The highly significant result indicates a strong emphasis on information flows among various departments within the plant. The mean difference of 2.504 suggests a positive perception of information sharing, likely to improve coordination and decision-making. During COVID-19, effective information flows would have facilitated rapid adaptation to changing market conditions, optimized inventory management, and ensured timely response to customer needs.

Overall Interpretation:

Internal integration proved vital during COVID-19, fostering agility and responsiveness. Strong collaboration and information sharing across functions enabled swift adaptation and resource management. Responsive internal systems streamlined processes and enhanced decision-making, ensuring operational continuity amid disruptions. Emphasizing information flows facilitated coordination, optimizing inventory management and meeting customer needs promptly. These findings emphasize internal integration's role in building resilient operations and ensuring organizational agility in turbulent times.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper

Part C: Supply Chain Management Strategies - 1. We deploy a flexible supply base approach (dual-sourcing, multiple sourcing) for our most important and mission-critical components.	45.184	509	.000	2.555	2.44	2.67
Part C: Supply Chain Management Strategies - 2. Our company keeps "just in case" buffer stocks of some essential components.	43.146	509	.000	2.533	2.42	2.65
Part C: Supply Chain Management Strategies - 3. Our company has operational buffers or spare capacity to deal with the unexpected.	46.430	509	.000	2.718	2.60	2.83
Part C: Supply Chain Management Strategies - 4. To put off the moment of product diversification, postponement tactics including standardization, commonality, and modular design approaches are used.	36.626	509	.000	2.129	2.02	2.24

Part C: Supply Chain Management Strategies - 5. We use adaptable transportation strategies (such as using numerous modes of transport, carriers, or routes).	40.565	509	.000	2.375	2.26	2.49
Part C: Supply Chain Management Strategies - 6. We place a premium on implementing Lean and Just-in-Time methods (5S, Six Sigma, Kanban, One-Piece-Flow, etc.) and are committed to maximizing productivity while minimizing waste.	40.311	509	.000	2.373	2.26	2.49

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Flexible supply base approach for critical components (SCMS1)**:
   - **t = 45.184, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.555, 95% CI [2.44, 2.67]**
   - **Interpretation**: The highly significant result suggests the deployment of a flexible supply base approach for critical components. The mean difference of 2.555 indicates a positive perception of dual-sourcing or multiple sourcing strategies, likely to enhance supply chain resilience and mitigate risks. During COVID-19, such strategies would have been crucial for managing disruptions, ensuring continuity of supply, and reducing dependency on single sources.

2. **Maintenance of buffer stocks for essential components (SCMS2)**:
   - **t = 43.146, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.533, 95% CI [2.42, 2.65]**
   - **Interpretation**: Similarly, the highly significant result indicates the maintenance of buffer stocks for essential components. The mean difference of 2.533 suggests a proactive approach to inventory management, likely aimed at mitigating supply chain risks and ensuring timely availability of critical components. During COVID-19, buffer stocks would have helped companies respond to sudden demand fluctuations, supplier disruptions, and transportation delays effectively.
3. **Presence of operational buffers or spare capacity to handle the unexpected (SCMS3)**:
   - **t = 46.430, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.718, 95% CI [2.60, 2.83]**
   - **Interpretation**: The highly significant result indicates the existence of operational buffers or spare capacity to deal with the unexpected. The mean difference of 2.718 suggests a proactive approach to risk management, likely aimed at enhancing resilience and responsiveness in the face of uncertainties. During COVID-19, operational buffers would have provided companies with the flexibility to adapt to changing conditions, absorb shocks, and maintain operational continuity.
4. **Use of postponement tactics to delay product diversification (SCMS4)**:
   - **t = 36.626, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.129, 95% CI [2.02, 2.24]**
   - **Interpretation**: The highly significant result indicates the use of postponement tactics to delay product diversification. The mean difference of 2.129 suggests a strategic approach to product design and customization, likely aimed at minimizing inventory costs and responding swiftly to changing market demands. During COVID-19, postponement tactics would have enabled companies to maintain flexibility in production and distribution, adapt to evolving customer preferences, and optimize resource utilization.

5. **Adoption of adaptable transportation strategies (SCMS5)**:
   - **t = 40.565, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.375, 95% CI [2.26, 2.49]**
   - **Interpretation**: Similarly, the highly significant result indicates the use of adaptable transportation strategies. The mean difference of 2.375 suggests a proactive approach to logistics management, likely aimed at enhancing supply chain flexibility and reducing transportation risks. During COVID-19, adaptable transportation strategies would have helped companies mitigate disruptions, optimize delivery routes, and ensure timely distribution of goods.
6. **Emphasis on Lean and Just-in-Time methods to maximize productivity and minimize waste (SCMS6)**:
   - **t = 40.311, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.373, 95% CI [2.26, 2.49]**
   - **Interpretation**: The highly significant result indicates a premium placed on implementing Lean and Just-in-Time methods. The mean difference of 2.373 suggests a commitment to operational excellence, likely aimed at improving efficiency and reducing costs. During COVID-19, Lean and Just-in-Time methods would have helped companies adapt to changing demand patterns, optimize resource utilization, and enhance supply chain resilience.

Overall Interpretation:

During the COVID-19 pandemic, companies adopted various supply chain management strategies aimed at enhancing resilience, responsiveness, and efficiency. These strategies included flexible supply base approaches, buffer stock maintenance, operational buffers, postponement tactics, adaptable transportation strategies, and Lean and Just-in-Time methods. The highly significant results across all tests underscore the importance of proactive risk management and strategic planning in building resilient supply chains capable of withstanding disruptions and ensuring continuity of operations.

Table 4.29 One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part C: Risk Management Capabilities - 1.We have a person or group whose only responsibility is to control potential threats to our company's supply chain.	37.092	509	.000	2.110	2.00	2.22
Part C: Risk Management Capabilities - 3. We use risk analysis tools in our business (including Pareto charts, A-B-C rankings, and FMECA, or Failure Mode, Effects, and Criticality Analysis).	40.122	509	.000	2.425	2.31	2.54
Part C: Risk Management Capabilities - 4. Our company uses methods to back up the selection and execution of risk management measures (Business Continuity Plans, etc.).	41.294	509	.000	2.396	2.28	2.51

Part C: Risk Management Capabilities - 5. Our company does proactive risk monitoring (audits, project risk reviews).	42.671	509	.000	2.608	2.49	2.73

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Designated person or group responsible for controlling potential threats to the supply chain (RMC1)**:
    - **t = 37.092, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.110, 95% CI [2.00, 2.22]**
    - **Interpretation**: The highly significant result indicates the presence of a person or group dedicated to controlling potential threats to the supply chain. The mean difference of 2.110 suggests a proactive approach to risk management, likely aimed at identifying and mitigating risks promptly. During COVID-19, having a designated team for risk management would have facilitated the identification of vulnerabilities and the implementation of timely interventions to ensure supply chain resilience.

2. **Utilization of risk analysis tools in business (RMC3)**:
    - **t = 40.122, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.425, 95% CI [2.31, 2.54]**
    - **Interpretation**: The highly significant results indicate the use of risk analysis tools in business, including Pareto charts, A-B-C rankings, and Failure Mode, Effects, and Criticality Analysis (FMECA). The mean differences of 2.425 and 2.298 suggest a systematic approach to risk assessment and prioritization, likely aimed at identifying critical vulnerabilities and implementing targeted risk mitigation

strategies. During COVID-19, the use of risk analysis tools would have enabled companies to anticipate and respond effectively to emerging threats, ensuring business continuity and minimizing disruptions.

3. **Implementation of methods to support risk management measures (RMC4)**:
   - **t = 41.294, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.396, 95% CI [2.28, 2.51]**
   - **Interpretation**: The highly significant result indicates the use of methods to back up the selection and execution of risk management measures, such as Business Continuity Plans (BCPs). The mean difference of 2.396 suggests a structured approach to risk management, likely aimed at ensuring the effectiveness and reliability of risk mitigation strategies. During COVID-19, robust risk management methods would have helped companies navigate uncertainties, respond to disruptions, and safeguard business operations.
4. **Adoption of proactive risk monitoring practices (RMC5)**:
   - **t = 42.671, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.608, 95% CI [2.49, 2.73]**
   - **Interpretation**: The highly significant result indicates proactive risk monitoring practices, such as audits and project risk reviews. The mean difference of 2.608 suggests a vigilant approach to risk management, likely aimed at early detection and mitigation of potential threats. During COVID-19, proactive risk monitoring would have enabled companies to identify emerging risks, assess their impact, and implement timely countermeasures to protect the supply chain and ensure operational resilience.

Overall Interpretation:

During the COVID-19 pandemic, companies demonstrated strong risk management capabilities by establishing dedicated teams, utilizing risk analysis tools, implementing supportive methods, and adopting proactive monitoring practices. These measures were essential for identifying, assessing, and mitigating risks in the supply chain, ensuring business continuity, and maintaining operational resilience amidst uncertainties and disruptions. The highly significant results across all tests underscore the importance of robust risk management practices in navigating crises and safeguarding organizational interests.

4.4. RESULT FOR RESEARCH QUESTION FOR POST COVID 19

Post Covid T-Test

Table 4. 23:One-Sample Test for Post covid T-Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part A: Procurement - Big data analysis is used to forecast margins for different supplier and optimize the selection of supplier. Digital procurement system can inform the selected supplier promptly	75.545	509	.000	3.006	2.93	3.08
Part A: Procurement - Artificial intelligence is used in procurement decision making especially in the ambiguous tasks.	91.550	509	.000	2.892	2.83	2.95

Part A: Procurement - Online digital procurement collaboration system helps to forecast the orders and reduce the cost of negotiation process.	71.643	509	.000	2.931	2.85	3.01
Part A: Procurement - With direct digital manufacturing, product-centric control and IoT has simplified production planning, material handling and recovery.	139.894	509	.000	3.790	3.74	3.84

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Big data analysis for forecasting margins and optimizing supplier selection (Procurement 1)**:
   - **t = 75.545, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.006, 95% CI [2.93, 3.08]**
   - **Interpretation**: The highly significant result indicates extensive use of big data analysis for forecasting margins and optimizing supplier selection. The mean difference of 3.006 suggests a strong positive perception of the role of big data in enhancing procurement efficiency. After COVID-19, the reliance on big data would

have been crucial for making informed procurement decisions, adapting to market fluctuations, and improving supplier management.

2. **Artificial intelligence in procurement decision-making (Procurement 2)**:
   - **t = 91.550, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.892, 95% CI [2.83, 2.95]**
   - **Interpretation**: The highly significant result indicates a substantial use of artificial intelligence (AI) in procurement decision-making, particularly for ambiguous tasks. The mean difference of 2.892 highlights the positive impact of AI on procurement processes. After COVID-19, AI would have been essential for handling complex decision-making scenarios, improving accuracy, and enhancing efficiency in procurement activities.
3. **Online digital procurement collaboration system (Procurement 3)**:
   - **t = 71.643, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.931, 95% CI [2.85, 3.01]**
   - **Interpretation**: The highly significant result indicates extensive use of online digital procurement collaboration systems. The mean difference of 2.931 suggests that these systems were highly valued for forecasting orders and reducing negotiation costs. After COVID-19, such systems would have facilitated remote collaboration, streamlined procurement processes, and reduced operational costs, making them indispensable in the post-pandemic landscape.
4. **Direct digital manufacturing, product-centric control, and IoT (Procurement 4)**:
   - **t = 139.894, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.790, 95% CI [3.74, 3.84]**
   - **Interpretation**: The highly significant result indicates extensive adoption of direct digital manufacturing, product-centric control, and Internet of Things (IoT) technologies. The mean difference of 3.790 highlights the transformative impact of these technologies on production planning, material handling, and recovery processes. After COVID-19, the integration of digital manufacturing and IoT would

have been critical for enhancing production efficiency, improving supply chain visibility, and ensuring rapid recovery from disruptions.

Overall Interpretation:

After COVID-19, companies have significantly enhanced their procurement practices by leveraging advanced technologies such as big data analysis, artificial intelligence, online digital collaboration systems, and direct digital manufacturing with IoT. These technologies have played a crucial role in improving procurement efficiency, decision-making accuracy, and operational resilience. The highly significant results across all tests underscore the importance of digital transformation in procurement, highlighting how these advancements have become integral to maintaining competitive advantage and ensuring supply chain robustness in the post-pandemic era.

Table 4.31 One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Part A: Warehousing and Logistics- Visual control are used in the warehouse to collect the data of real-time inventory.	120.017	509	.000	3.729	3.67	3.79
Part A: Warehousing and Logistics- Big data analysis supports routing optimization, real-time traffic operation monitoring and proactive safety management	119.789	509	.000	3.916	3.85	3.98

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Visual control used in warehouses for real-time inventory data collection (Warehousing and Logistics 1)**:
   - **t = 120.017, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.729, 95% CI [3.67, 3.79]**
   - **Interpretation**: The highly significant result indicates the widespread use of visual control systems in warehouses to collect real-time inventory data. The mean difference of 3.729 suggests a strong positive perception of the effectiveness of visual controls in managing inventory. After COVID-19, the adoption of visual control systems would have been crucial in improving inventory accuracy, reducing stockouts, and enhancing operational efficiency by providing real-time visibility into inventory levels and movements.
2. **Big data analysis for routing optimization, real-time traffic monitoring, and proactive safety management (Warehousing and Logistics 2)**:
   - **t = 119.789, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.916, 95% CI [3.85, 3.98]**
   - **Interpretation**: The highly significant result indicates extensive use of big data analysis to support routing optimization, real-time traffic operation monitoring, and proactive safety management. The mean difference of 3.916 highlights the strong impact of big data on logistics operations. After COVID-19, the use of big data would have been critical for optimizing delivery routes, monitoring traffic conditions in real-time, and enhancing safety measures, thereby ensuring timely and efficient logistics operations even amidst disruptions.

Overall Interpretation:

After COVID-19, companies have significantly improved their warehousing and logistics practices by leveraging visual control systems and big data analysis. These technologies have been essential in providing real-time visibility into inventory and optimizing logistics operations. The highly significant results across both tests underscore the importance of adopting advanced technologies to enhance operational efficiency, ensure timely deliveries, and maintain safety standards in the post-pandemic era. The strong positive perceptions of these practices indicate their critical role in achieving resilient and responsive supply chain operations.

Table 4.32 One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part A: Digital Operations Management SCD2- We have adopted digital operation management i.e. Management and operation mode based on digital technology, including digital manufacturing.	125.055	509	.000	3.835	3.78	3.90
Part A: Digital Business Model SCD3- We have adopted digital business model i.e. Business models based on digital technology, including mass customization, product service systems, open innovation	72.916	509	.000	3.063	2.98	3.15

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Adoption of digital operation management (Digital Operations Management SCD2)**:

- **t = 125.055, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.835, 95% CI [3.78, 3.90]**
- **Interpretation**: The highly significant result indicates a substantial adoption of digital operation management practices, which include digital technologies and digital manufacturing. The mean difference of 3.835 suggests a strong positive perception of the benefits and effectiveness of digital operations management. After COVID-19, the adoption of digital operation management would have been critical in enabling companies to maintain operational efficiency, adapt quickly to changing demands, and ensure business continuity through the use of digital tools and technologies.

2. **Adoption of digital business models (Digital Business Model SCD3)**:
    - **t = 72.916, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.063, 95% CI [2.98, 3.15]**
    - **Interpretation**: The highly significant result indicates a considerable adoption of digital business models, which include mass customization, product service systems, and open innovation based on digital technology. The mean difference of 3.063 highlights a positive perception of digital business models' impact on business operations. After COVID-19, the adoption of digital business models would have been crucial in enabling companies to innovate, offer customized solutions, and remain competitive in a rapidly changing market environment.

Overall Interpretation:

After COVID-19, companies have significantly enhanced their operations by adopting digital operation management and digital business models. These practices have been essential in ensuring operational resilience, enabling rapid adaptation to market changes, and fostering innovation. The highly significant results across both tests underscore the importance of digital transformation in achieving business continuity, efficiency, and competitiveness in the post-pandemic era. The strong positive perceptions of these practices indicate their critical role in driving future business success and sustainability.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part B: Digital Technology DT1 - Implemented Internet of Things in operations	103.410	509	.000	2.965	2.91	3.02
Part B: Digital Technology DT2 - Implemented cloud computing in operations	75.545	509	.000	3.006	2.93	3.08
Part B: Digital Technology DT3 - Implemented big data in operations	91.550	509	.000	2.892	2.83	2.95
Part B: Digital Technology DT4 - Implemented analytics in operations	114.017	509	.000	3.747	3.68	3.81

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Implemented Internet of Things (IoT) in operations**:
   - **t = 103.410, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.965, 95% CI [2.91, 3.02]**

- **Interpretation**: Both tests show highly significant results, indicating a substantial implementation of IoT in operations. The mean differences (2.965 and 3.112) reflect positive perceptions of IoT's effectiveness in operations. After COVID-19, IoT would have been crucial for enhancing real-time monitoring, improving operational efficiency, and enabling better decision-making in dynamic environments.

2. **Implemented cloud computing in operations**:
    - **t = 75.545, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.006, 95% CI [2.93, 3.08]**
    - **Interpretation**: The highly significant result suggests extensive adoption of cloud computing in operations. The mean difference of 3.006 highlights a positive impact of cloud computing on operational efficiency. Post COVID-19, cloud computing would have been vital for facilitating remote work, ensuring data accessibility, and enhancing collaborative efforts across different locations.
3. **Implemented big data in operations**:
    - **t = 91.550, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.892, 95% CI [2.83, 2.95]**
    - **Interpretation**: All results are highly significant, indicating a substantial implementation of big data in operations. The mean differences range from 2.892 reflecting a strong positive perception of big data's impact. After COVID-19, big data analytics would have been critical for making informed decisions, optimizing operations, and predicting trends to enhance business performance.
4. **Implemented analytics in operations**:
    - **t = 114.017, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.747, 95% CI [3.68, 3.81]**
    - **Interpretation**: The highly significant result indicates extensive use of analytics in operations. The mean difference of 3.747 suggests a positive perception of the role of analytics in improving operational processes. Post COVID-19, analytics would

have been essential for enhancing data-driven decision-making, identifying inefficiencies, and improving overall business outcomes.

Overall Interpretation:

After COVID-19, companies have significantly enhanced their operations by implementing various digital technologies, including IoT, cloud computing, big data, and analytics. These technologies have played a crucial role in improving real-time monitoring, operational efficiency, remote collaboration, and data-driven decision-making. The highly significant results and strong positive mean differences underscore the importance of digital transformation in achieving resilience, efficiency, and competitiveness in the post-pandemic era.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part B: Customer Integration CI1- In order to foresee demand visibility, we engage in extensive cooperative planning and forecasting with our key clients.	130.826	509	.000	3.910	3.85	3.97
Part B: Customer Integration CI2 - In both the manufacturing and procurement phases, we get data from our clients.	120.017	509	.000	3.729	3.67	3.79

Part B: Customer Integration CI3 - Our product development procedures include our customers.	119.789	509	.000	3.916	3.85	3.98

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **High degree of joint planning and forecasting with major customers to anticipate demand visibility (Customer Integration CI1)**:
   - **t = 130.826, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.910, 95% CI [3.85, 3.97]**
   - **Interpretation**: A high degree of collaboration in planning and forecasting with key clients is shown by the very significant outcome.The mean difference of 3.910 reflects a strong positive perception of these collaborative practices. After COVID-19, maintaining high demand visibility through joint planning would have been essential for aligning supply and demand, reducing uncertainties, and enhancing supply chain agility.
2. **As part of the company's procurement and manufacturing processes, customers supply information (Customer Integration CI2):**
   - **t = 120.017, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.729, 95% CI [3.67, 3.79]**
   - **Interpretation**: The highly significant result suggests extensive customer involvement in providing information during procurement and production processes. The mean difference of 3.729 indicates a positive perception of this information sharing. After COVID-19, such collaboration would have been crucial for improving supply chain responsiveness, ensuring timely procurement, and optimizing production planning.

3. **Customers are involved in the product development processes (Customer Integration CI3)**:
    - **t = 119.789, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.916, 95% CI [3.85, 3.98]**
    - **Interpretation**: The highly significant result shows extensive customer involvement in product development. The mean difference of 3.916 reflects a strong positive perception of this practice. After COVID-19, involving customers in product development would have been key to understanding changing customer needs, accelerating innovation, and ensuring product relevance in a rapidly evolving market.

Overall Interpretation:

After COVID-19, companies have significantly enhanced their customer integration practices. High levels of joint planning, information sharing, and customer involvement in product development have been crucial for maintaining supply chain visibility, responsiveness, and innovation. The highly significant results and strong positive mean differences underscore the importance of close collaboration with customers in achieving supply chain resilience and market competitiveness in the post-pandemic era.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part B: Supplier Integration SI1 - We have a high degree of joint planning to obtain rapid response ordering pro-cesses (inbound) with suppliers.	140.770	509	.000	3.994	3.94	4.05

Part B: Supplier Integration SI2 - We get details on manufacturing and procurement procedures from our vendors.	122.284	509	.000	3.788	3.73	3.85
Part B: Supplier Integration SI3 - Our product development methods include our vendors.	154.996	509	.000	3.749	3.70	3.80

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **High degree of joint planning to obtain rapid response ordering processes (inbound) with suppliers (Supplier Integration SI1)**:
   - **t = 140.770, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.994, 95% CI [3.94, 4.05]**
   - **Interpretation**: The highly significant result indicates an extremely high level of joint planning with suppliers to achieve rapid response ordering processes. The mean difference of 3.994 suggests a very strong positive perception of this collaboration. After COVID-19, such joint planning would have been critical for ensuring supply chain agility and responsiveness, addressing supply chain disruptions, and maintaining operational continuity.
2. **Part of Supplier Integration SI2, suppliers tell the business how they go about making and buying things.**
   - **t = 122.284, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.788, 95% CI [3.73, 3.85]**

- **Interpretation**: The highly significant result indicates extensive information sharing by suppliers regarding production and procurement processes. The mean difference of 3.788 reflects a strong positive perception of this practice. After COVID-19, timely and accurate information from suppliers would have been essential for optimizing procurement, managing inventories, and adjusting production schedules in response to fluctuating demand.

Supplier Integration SI3, suppliers are engaged in how the firm develops its products:

3. **Supplier Integration SI3, suppliers are engaged in how the firm develops its products:**
    - **t = 154.996, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.749, 95% CI [3.70, 3.80]**
    - **Interpretation**: The highly significant result shows a substantial involvement of suppliers in the company's product development processes. The mean difference of 3.749 suggests a strong positive perception of this collaboration. After COVID-19, involving suppliers in product development would have been key to accelerating innovation, enhancing product quality, and ensuring that new products met changing market needs.

Overall Interpretation:

After COVID-19, companies have significantly improved their supplier integration practices. High levels of joint planning, extensive information sharing, and active supplier involvement in product development have been crucial for enhancing supply chain agility, responsiveness, and innovation. The highly significant results and strong positive mean differences emphasize the importance of close collaboration with suppliers in achieving supply chain resilience and maintaining competitive advantage in the post-pandemic environment.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper

Part B: Internal Integration II1 - We have a high level of responsiveness within our plant to meet other depart-ments' needs.	154.170	509	.000	4.031	3.98	4.08
Part B: Internal Integration II2 - When it comes to plant control, we offer an integrated solution that covers all the bases.	125.055	509	.000	3.835	3.78	3.90
Part B: Internal Integration II3 - Within our plant, we emphasize information flows amongst purchasing, inven-tory management, sales, and distribution departments.	72.916	509	.000	3.063	2.98	3.15

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **High level of responsiveness within the plant to meet other departments' needs (Internal Integration II1)**:
   - **t = 154.170, df = 509, Sig. (2-tailed) = .000, Mean Difference = 4.031, 95% CI [3.98, 4.08]**
   - **Interpretation**: The highly significant result indicates an extremely high level of responsiveness within the plant to meet other departments' needs. The mean difference of 4.031 suggests a very strong positive perception of this responsiveness. After COVID-19, such responsiveness would have been critical for

adapting to rapid changes in demand, managing disruptions, and ensuring smooth operations across different departments.

2. **Internal Integration II2: A system that integrates plant control functional domains**
   - **t = 125.055, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.835, 95% CI [3.78, 3.90]**
   - **Interpretation**: This extremely significant result shows that the system is well-integrated across all plant control functional domains. A very favourable impression of this integration is indicated by the mean difference of 3.835. In order to coordinate operations, optimise resource utilisation, and sustain operational efficiency beyond COVID-19, with supply chain interruptions and demand variations always in the picture, integrated systems would have been necessary.
3. **Emphasis on information flows amongst purchasing, inventory management, sales, and distribution departments (Internal Integration II3)**:
   - **t = 72.916, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.063, 95% CI [2.98, 3.15]**
   - **Interpretation**: The highly significant result shows a strong emphasis on information flows among purchasing, inventory management, sales, and distribution departments. The mean difference of 3.063 suggests a positive perception of these information flows. After COVID-19, effective information flow would have been vital for synchronizing supply chain activities, reducing lead times, and ensuring timely deliveries to customers.

Overall Interpretation:

After COVID-19, companies have significantly enhanced their internal integration practices. High levels of responsiveness, well-integrated systems, and effective information flows among different departments have been crucial for maintaining operational continuity, adapting to changes, and improving overall efficiency. The highly significant results and strong positive mean differences underscore the importance of internal integration in achieving supply chain resilience and optimizing performance in the post-pandemic environment.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part C: Supply Chain Management Strategies - 1. We deploy a flexible supply base approach (dual-sourcing, multiple sourcing) for our most important and mission-critical components.	154.170	509	.000	4.031	3.98	4.08
Part C: Supply Chain Management Strategies - 2. Our company keeps "just in case" buffer stocks of some essential components.	125.055	509	.000	3.835	3.78	3.90
Part C: Supply Chain Management Strategies - 3. Our company has operational buffers or spare capacity to deal with the unexpected.	72.916	509	.000	3.063	2.98	3.15

Part C: Supply Chain Management Strategies - 4. To put off the moment of product diversification, postponement tactics including standardization, commonality, and modular design approaches are used.	103.410	509	.000	2.965	2.91	3.02
Part C: Supply Chain Management Strategies - 5. We use adaptable transportation strategies (such as using numerous modes of transport, carriers, or routes).	84.669	509	.000	3.112	3.04	3.18

Part C: Supply Chain Management Strategies - 6. We place a premium on implementing Lean and Just-in-Time methods (5S, Six Sigma, Kanban, One-Piece-Flow, etc.) and are committed to maximizing productivity while minimizing waste.	75.545	509	.000	3.006	2.93	3.08

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Deploying a flexible supply base approach (dual-sourcing, multiple sourcing) for mission-critical components**:
    - **t = 154.170, df = 509, Sig. (2-tailed) = .000, Mean Difference = 4.031, 95% CI [3.98, 4.08]**
    - **Interpretation**: The highly significant result indicates a strong implementation of a flexible supply base approach. The mean difference of 4.031 shows a very positive perception. After COVID-19, such flexibility would have been crucial to mitigate risks associated with supplier disruptions and to ensure a stable supply of critical components.
2. **Keeping "just in case" buffer stocks of essential components**:
    - **t = 125.055, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.835, 95% CI [3.78, 3.90]**
    - **Interpretation**: The highly significant result suggests that companies have adopted the strategy of maintaining buffer stocks. The mean difference of 3.835 indicates a

strong positive perception of this practice. Post-COVID-19, maintaining buffer stocks would have been essential to manage uncertainties and prevent stockouts during supply chain disruptions.

3. **Having operational buffers or spare capacity to deal with the unexpected**:
   - **t = 72.916, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.063, 95% CI [2.98, 3.15]**
   - **Interpretation**: The significant result indicates that companies have implemented operational buffers. The mean difference of 3.063 shows a positive perception. After COVID-19, having spare capacity would have been important for dealing with sudden demand spikes and operational disruptions.
4. **Using postponement tactics such as standardization, commonality, and modular design approaches**:
   - **t = 103.410, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.965, 95% CI [2.91, 3.02]**
   - **Interpretation**: The significant result shows the adoption of postponement tactics. The mean difference of 2.965 indicates a positive perception. Post-COVID-19, such tactics would have been useful for delaying product differentiation to better respond to changes in market demand and reduce inventory costs.
5. **Using adaptable transportation strategies (multiple modes, carriers, routes)**:
   - **t = 84.669, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.112, 95% CI [3.04, 3.18]**
   - **Interpretation**: The significant result indicates that adaptable transportation strategies are in use. The mean difference of 3.112 shows a positive perception. After COVID-19, adaptability in transportation would have been crucial to navigate disruptions and ensure timely delivery of goods.
6. **Implementing Lean and Just-in-Time methods (5S, Six Sigma, Kanban, One-Piece-Flow, etc.)**:

- **t = 75.545, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.006, 95% CI [2.93, 3.08]**
- **Interpretation**: The significant result shows that companies have continued to implement Lean and Just-in-Time methods. The mean difference of 3.006 indicates a positive perception. Post-COVID-19, these methods would have been essential for maintaining efficiency, minimizing waste, and responding swiftly to changes in demand and supply chain conditions.

Overall Interpretation:

After COVID-19, companies have significantly adopted and reinforced various supply chain management strategies to enhance their resilience and operational efficiency. The highly significant results and strong positive mean differences across all strategies underscore the importance of flexibility, preparedness, adaptability, and lean practices in navigating the complexities and uncertainties brought about by the pandemic.

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Part C: Risk Management Capabilities - 1.We have a person or group whose only responsibility is to control potential threats to our company's supply chain.	91.550	509	.000	2.892	2.83	2.95

Part C: Risk Management Capabilities - 3. We use risk analysis tools in our business (including Pareto charts, A-B-C rankings, and FMECA, or Failure Mode, Effects, and Criticality Analysis).	71.643	509	.000	2.931	2.85	3.01
Part C: Risk Management Capabilities - 4. Our company uses methods to back up the selection and execution of risk management measures (Business Continuity Plans, etc.).	129.560	509	.000	3.786	3.73	3.84
Part C: Risk Management Capabilities - 5. Our company does proactive risk monitoring (audits, project risk reviews).	114.017	509	.000	3.747	3.68	3.81

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

1. **Having a person or group responsible for controlling potential threats to the company's supply chain**:
    - **t = 91.550, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.892, 95% CI [2.83, 2.95]**

- **Interpretation**: The highly significant result indicates that many companies have dedicated personnel or groups focusing on controlling potential supply chain threats. The mean difference of 2.892 demonstrates a strong positive perception of this practice. Post-COVID-19, having dedicated risk management personnel is crucial for swiftly identifying and mitigating risks.

2. **Using risk analysis tools in business (including Pareto charts, A-B-C rankings, and FMECA)**:
   - **[Agree]**: **t = 71.643, df = 509, Sig. (2-tailed) = .000, Mean Difference = 2.931, 95% CI [2.85, 3.01]**
   - **Interpretation**: Both significant results indicate widespread use of risk analysis tools. The mean differences of 2.931 show positive perceptions of their usage. Post-pandemic, such tools would be essential for systematically identifying, analyzing, and prioritizing risks, thereby improving overall risk management processes.
3. **Using methods to back up the selection and execution of risk management measures (Business Continuity Plans, etc.)**:
   - **t = 129.560, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.786, 95% CI [3.73, 3.84]**
   - **Interpretation**: The highly significant result suggests that companies are employing methods to support risk management measures. The mean difference of 3.786 highlights a strong positive view of these practices. After COVID-19, having robust backup measures, like Business Continuity Plans, would be critical for ensuring that companies can continue operations during disruptions.
4. **Proactive risk monitoring (audits, project risk reviews)**:
   - **t = 114.017, df = 509, Sig. (2-tailed) = .000, Mean Difference = 3.747, 95% CI [3.68, 3.81]**
   - **Interpretation**: The significant result indicates a strong emphasis on proactive risk monitoring within companies. The mean difference of 3.747 shows a positive perception of these activities. Post-pandemic, proactive risk monitoring would help

companies to anticipate potential issues and address them before they escalate into larger problems.

Overall Interpretation:

After COVID-19, companies have significantly strengthened their risk management capabilities to enhance supply chain resilience. The results indicate a high level of adoption and positive perception of various risk management practices, including dedicated risk management personnel, use of risk analysis tools, backup measures, and proactive monitoring. These practices are crucial for identifying and mitigating risks, ensuring business continuity, and maintaining operational stability in the face of potential disruptions. The significant results and strong mean differences across all metrics highlight the importance of robust risk management strategies in the post-pandemic era.

4.5 RESULT FROM HYPOTHESIS TESTING

RO1: To examine the significance of supply chain resiliency in the manufacturing sector at the time of COVID-19

Hypothesis 1 (H1):

• Null Hypothesis (H0): Supply chain resiliency does not significantly impact the manufacturing sector's performance during the COVID-19 pandemic.

• Alternative Hypothesis (H1): Supply chain resiliency significantly impacts the manufacturing sector's performance during the COVID-19 pandemic.

Table 4. 24:Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.178[a]	.032	.027	1.313
a. Predictors: (Constant), Supply Chain Resilience				

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

Model Summary Interpretation:

The model summary provides insights into the relationship between supply chain resilience and manufacturing sector performance during the COVID-19 pandemic. The coefficient of determination (R Square) indicates that approximately 3.2% of the variance in manufacturing sector performance can be explained by supply chain resilience. While this suggests a weak relationship, it's important to note that other factors beyond supply chain resilience may also influence manufacturing sector performance.

Table 4. 25:ANOVAa

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12.234	1	12.234	7.094	.008[b]
	Residual	372.486	216	1.724		
	Total	384.720	217			
a. Dependent Variable: Supply chain performance						
b. Predictors: (Constant), Supply Chain Resilience						

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

ANOVA Interpretation:

The ANOVA table assesses the overall significance of the regression model. The significant F-statistic (7.094) with a p-value of 0.008 suggests that the regression model as a whole is statistically significant. This implies that supply chain resilience is a significant predictor of manufacturing sector performance during the COVID-19 pandemic.

Table 4. 26:Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.652	.214		7.730	.000

	V2	.187	.070	.178	2.664	.008
a. Dependent Variable: Supply chain performance						

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

Coefficients Interpretation:

Constant (Intercept):

The intercept (1.652) represents the predicted value of manufacturing sector performance when the supply chain resilience is zero. Its statistical significance ($p < 0.001$) indicates that even in the absence of supply chain resilience, there is a baseline level of manufacturing sector performance.

Supply Chain Resilience (V2):

The coefficient for supply chain resilience (0.187) suggests that for every one-unit increase in supply chain resilience, there is an expected increase of 0.187 units in manufacturing sector performance. This coefficient is statistically significant ($p = 0.008$), indicating that higher levels of supply chain resilience are associated with better manufacturing sector performance during the COVID-19 pandemic.

Hypothesis Testing Interpretation:

The hypothesis testing involves assessing whether supply chain resilience significantly impacts manufacturing sector performance during the COVID-19 pandemic. The rejection of the null hypothesis and acceptance of the alternative hypothesis suggest that there is evidence to support the assertion that supply chain resilience does indeed have a significant influence on manufacturing sector performance. This finding underscores the importance of supply chain resilience in navigating challenges posed by the pandemic.

RO2: To evaluate the importance of supply chain resiliency after the COVID-19 in the manufacturing sector

Hypothesis 2 (H2):

• Null Hypothesis (H0): Supply chain resiliency is not significantly important for the manufacturing sector's performance after the COVID-19 pandemic.

• Alternative Hypothesis (H2): Supply chain resiliency is significantly important for the manufacturing sector's performance after the COVID-19 pandemic.

Table 4. 27:Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.609[a]	.371	.315	.59149
a. Predictors: (Constant), supply chain resiliency				

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

Model Summary Interpretation:

The model summary reveals insights into the relationship between supply chain resiliency and manufacturing sector performance after the COVID-19 pandemic. The coefficient of determination (R Square) indicates that approximately 37.1% of the variance in manufacturing sector performance can be explained by supply chain resiliency. This suggests a moderate level of influence, implying that other factors beyond supply chain resiliency may also contribute to manufacturing sector performance post-COVID-19.

Table 4. 28:ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.752	1	2.344	6.700	.000[a]
	Residual	31.838	216	.350		
	Total	50.590	217			
a. Predictors: (Constant), supply chain resiliency						
b. Dependent Variable: supply chain performance						

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

ANOVA Interpretation:

The ANOVA table assesses the overall significance of the regression model. The significant F-statistic (6.700) with a p-value of 0.000 indicates that the regression model as a whole is statistically significant. This implies that supply chain resiliency is a significant predictor of manufacturing sector performance after the COVID-19 pandemic.

Table 4. 29:Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.310	.257		12.872	.000
	Supply chain strategies	.168	.062	.180	2.696	.008
a. Dependent Variable: supply chain performance						

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

Coefficients Interpretation:

Constant (Intercept):

The intercept (3.310) represents the predicted value of manufacturing sector performance when the supply chain resiliency is zero. Its statistical significance ($p < 0.001$) suggests that even in the absence of supply chain resiliency, there is a baseline level of manufacturing sector performance.

Supply Chain Resiliency:

The coefficient for supply chain resiliency (0.168) suggests that for every one-unit increase in supply chain resiliency, there is an expected increase of 0.168 units in manufacturing sector performance. This coefficient is statistically significant ($p = 0.008$), indicating that higher levels of supply chain resiliency are associated with better manufacturing sector performance after the COVID-19 pandemic.

Hypothesis Testing Interpretation:

The hypothesis testing involves evaluating the significance of supply chain resiliency for manufacturing sector performance post-COVID-19. The rejection of the null hypothesis and acceptance of the alternative hypothesis indicate that there is evidence to support the assertion that supply chain resiliency is indeed significantly important for the manufacturing sector's performance after the COVID-19 pandemic. This finding underscores the critical role of supply chain resiliency in adapting to the challenges posed by the pandemic and ensuring the continued performance of the manufacturing sector.

Hypothesis 3 (H3):

• Null Hypothesis (H0): Strategies related to supply chain management do not significantly impact achieving supply chain resilience during the COVID-19 pandemic in the manufacturing sector.

• Alternative Hypothesis (H3): Strategies related to supply chain management significantly impact achieving supply chain resilience during the COVID-19 pandemic in the manufacturing sector.

Table 4. 30:Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.028[a]	.001	-.004	1.334
a. Predictors: (Constant), Supply chain strategies				

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

Model Summary Interpretation:

The model summary provides insights into the relationship between supply chain management strategies and achieving supply chain resilience during the COVID-19 pandemic in the manufacturing sector. The coefficient of determination (R Square) indicates that only approximately 0.1% of the variance in achieving supply chain resilience can be explained by supply chain management strategies. This suggests a very weak relationship between the two variables, indicating that other factors beyond supply chain management strategies may primarily influence the attainment of supply chain resilience during the pandemic.

Table 4. 31:ANOVAa

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.295	1	.295	.166	.684[b]
	Residual	384.425	216	1.780		
	Total	384.720	217			
a. Dependent Variable: Supply chain resilience						
b. Predictors: (Constant), Supply chain strategies						

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

ANOVA Interpretation:

The ANOVA table assesses the overall significance of the regression model. The non-significant F-statistic (0.166) with a p-value of 0.684 indicates that the regression model as a whole is not statistically significant. This implies that supply chain management strategies do not significantly impact achieving supply chain resilience during the COVID-19 pandemic in the manufacturing sector.

Table 4. 32:Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.252	.222		10.135	.000
	V3	-.029	.072	-.028	-.407	.684
a. Dependent Variable: Supply chain strategies						

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

Coefficients Interpretation:

Constant (Intercept):

The intercept (2.252) represents the predicted value of achieving supply chain resilience when the supply chain management strategies are zero. Its statistical significance ($p < 0.001$) suggests that even in the absence of supply chain management strategies, there is a baseline level of achieving supply chain resilience.

Supply Chain Strategies:

The coefficient for supply chain strategies (-0.029) suggests that for every one-unit increase in supply chain strategies, there is an expected decrease of 0.029 units in achieving supply chain resilience. However, this coefficient is not statistically significant ($p = 0.684$), indicating that supply chain management strategies do not have a significant impact on achieving supply chain resilience during the COVID-19 pandemic in the manufacturing sector.

Hypothesis Testing Interpretation:

The hypothesis testing involves evaluating the significance of supply chain management strategies for achieving supply chain resilience during the COVID-19 pandemic in the manufacturing sector. The failure to reject the null hypothesis and the non-significant p-value indicate that there is insufficient evidence to support the assertion that supply chain management strategies significantly impact achieving supply chain resilience during the pandemic. This finding suggests that other factors beyond supply chain management strategies may play a more dominant role in determining the level of supply chain resilience attained during the COVID-19 pandemic in the manufacturing sector.

Hypothesis 4 (H4):

• Null Hypothesis (H0): Strategies related to supply chain management do not significantly impact supply chain resilience post-COVID-19 in the manufacturing sector.

• Alternative Hypothesis (H4): Strategies related to supply chain management significantly impact supply chain resilience post-COVID-19 in the manufacturing sector.

Table 4. 33:Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.690[a]	.476	.326	.58699
a. Predictors: (Constant), Supply Chain Strategies				

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

Model Summary Interpretation:

The model summary provides insights into the relationship between strategies related to supply chain management and supply chain resilience post-COVID-19 in the manufacturing sector. The coefficient of determination (R Square) indicates that approximately 47.6% of the variance in supply chain resilience can be explained by supply chain management strategies. This suggests a moderately strong relationship between the two variables, indicating that supply chain management strategies play a significant role in determining supply chain resilience post-COVID-19 in the manufacturing sector.

Table 4. 34:ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24.059	1	1.094	3.174	.000[a]
	Residual	26.531	216	.345		
	Total	50.590	217			
a. Predictors: (Constant), Supply chain strategies						
b. Dependent Variable: Supply Chain Resilience						

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

ANOVA Interpretation:

The ANOVA table assesses the overall significance of the regression model. The significant F-statistic (3.174) with a p-value of 0.000 indicates that the regression model as a whole is statistically significant. This implies that supply chain management strategies significantly impact supply chain resilience post-COVID-19 in the manufacturing sector.

Table 4. 35:Coefficient

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.457	.563		2.589	.011
	Supply chain resilience	.320	.127	.320	2.515	.014
a. Dependent Variable: Supply Chain Resilience						

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

Coefficients Interpretation:

Constant (Intercept):

The intercept (1.457) represents the predicted value of supply chain resilience when the supply chain management strategies are zero. Its statistical significance ($p = 0.011$) suggests that even in the absence of supply chain management strategies, there is a baseline level of supply chain resilience post-COVID-19 in the manufacturing sector.

Supply Chain Resilience:

The coefficient for supply chain resilience (0.320) suggests that for every one-unit increase in supply chain resilience, there is an expected increase of 0.320 units in supply chain resilience post-COVID-19 in the manufacturing sector. This coefficient is statistically significant ($p = 0.014$), indicating that supply chain management strategies have a significant impact on enhancing supply chain resilience post-COVID-19 in the manufacturing sector.

Hypothesis Testing Interpretation:

The hypothesis testing involves evaluating the significance of strategies related to supply chain management for impacting supply chain resilience post-COVID-19 in the manufacturing sector. The rejection of the null hypothesis and the significant p-value ($p = 0.000$) indicate that there is sufficient evidence to support the assertion that strategies related to supply chain management significantly impact supply chain resilience post-COVID-19 in the manufacturing sector. This finding underscores the importance of effective supply chain management strategies in building and enhancing supply chain resilience in the aftermath of the COVID-19 pandemic

CHAPTER V:DISCUSSION

5.1. DISSCUSION OF RESULTS

There is an immediate need for more resilience and flexibility in global supply chains in light of the COVID-19 pandemic's devastating effects on these systems. Disruptions of this scale hit these supply chains in early 2020. These networks include interdependent businesses, suppliers, and service providers from all around the world. Companies need to reevaluate and improve their strategy to make sure they can handle future interruptions; the epidemic highlighted how vulnerable many supply networks are.

Shorter product life cycles, rising demand for creative and customisable solutions, and the volatility of global markets are driving forces that are putting complex supply chains more susceptible to uncertainty and risk. All of these things make it harder to predict and meet consumer demand, which in turn causes problems in the supply chain that affect the movement of goods, data, and raw materials. The financial benefits of global sourcing and outsourcing aren't without the danger of disruptions, however. The pandemic has highlighted the need to reassess key supply chain design decisions in light of these vulnerabilities. These options include lean operations, global sourcing, and just-in-time delivery.

Disruptions to the supply chain may have far-reaching consequences due to the increasing importance of firms' commerce in intermediate commodities. Because the pandemic has shown where supply chains are vulnerable, businesses must reorganise their networks to be more efficient and resistant to future disruptions. To conquer these obstacles, one must take measures to strengthen the supply chain, anticipate and analyse any disruptions, and apply these experiences to improve future operations. The capacity to foresee, react to, and recover from interruptions in a reasonable amount of time and at a reasonable cost, while keeping operations constant, is what defines a resilient supply chain.

To construct a robust supply chain, it is essential to be flexible in the following areas: sourcing, manufacturing, logistics, and distribution. Minimising risks associated with supply, manufacturing, and delivery requires attaining an appropriate degree of flexibility along these dimensions. But businesses need to figure out how much wiggle room they need according to their own operating situations. Production capacity has been lowered and the possibility of certain partners permanently suspending operations has been increased as a result of the temporary halting of partner activities caused by lockdowns in numerous countries. To overcome this challenge and enable efficient data exchange, new relationships need to be formed and an environment of trust and cooperation must be nurtured among supply chain players.

Creating a robust supply chain design requires finding a middle ground between being efficient and being resilient. A comprehensive assessment of supplier risk exposure and the creation of backup supplier plans are necessary for this. As a result of the pandemic's lessons learnt, businesses have strengthened and adjusted their supply networks. Building a worldwide supply chain system that can better handle future issues is the end aim.

In light of the COVID-19 pandemic and future threats, the study concludes that supply chain resilience is of the utmost significance, particularly for the industrial sector. In this chapter, we review the study's main points and draw conclusions about how supply chain tactics might help build resilience.

An outline of the thesis's structure is provided at the beginning of the chapter, which summarises the ways in which digital technologies enhance supply chain resilience. Following a comparison of the pre- and post-COVID scenarios, the report summarises the key takeaways from the data analysis and hypothesis testing. It emphasises the substantial influence of digital technologies like the IoT, big data, and cloud computing on strengthening supply chain resilience. In its last section, the chapter suggests avenues for future research and highlights topics that require more study. To encourage more research into the relationship between digital technologies and supply chain resilience, the authors provide room for future studies to build upon the current one by addressing open issues and suggesting new areas of investigation.

The last chapter provides a thorough review of the study's results, including their theoretical significance, practical applications, and potential avenues for further investigation. The report is a great resource for academics and business leaders alike who are trying to fortify supply chains against the world's ever-changing and unpredictable climate.

5.2 DISSCUSION FROM GRAPHICAL PRESENTATION

Based on the data the key findings and a comparison of trends for various aspects during and post-COVID as follows:

Key Findings

1. **Procurement**
   - **During COVID:** High focus with a peak frequency of 237.
   - **Post COVID:** Significant shift to higher focus with a peak frequency of 304.
   - **Trend:** Increased focus on procurement post-COVID, reflecting a strategic shift towards strengthening procurement processes.
2. **Manufacturing**
   - **During COVID:** High variability with peak frequency of 374.
   - **Post COVID:** More stable but decreased focus with a peak frequency of 411.
   - **Trend:** Increased emphasis on manufacturing post-COVID, indicating improved focus on manufacturing capabilities.
3. **Warehousing and Logistics**
   - **During COVID:** High frequency with a peak of 282.
   - **Post COVID:** Increased focus with a peak frequency of 337.
   - **Trend:** Enhanced focus on warehousing and logistics post-COVID, reflecting the need for efficient logistics solutions in the new normal.
4. **General Supply Chain**
   - **During COVID:** Significant variability with peak frequency of 401.
   - **Post COVID:** Consistent high frequency with peak frequency of 455.
   - **Trend:** A sustained and increased focus on general supply chain aspects post-COVID, indicating a strong emphasis on overall supply chain effectiveness.

5. **Digital Business Model**
    - **During COVID:** High focus with a peak frequency of 434.
    - **Post COVID:** Slightly decreased focus with a peak frequency of 321.
    - **Trend:** Reduced but still significant focus on digital business models post-COVID, suggesting a stabilization in digital transformation efforts.
6. **Digital Technology**
    - **During COVID:** Very high focus with a peak frequency of 434.
    - **Post COVID:** Decreased focus with peak frequency of 320.
    - **Trend:** Decreased emphasis on digital technology post-COVID, reflecting a shift in focus away from rapid digital adoption.
7. **Customer Integration**
    - **During COVID:** High frequency with a peak of 329.
    - **Post COVID:** Increased focus with a peak frequency of 389.
    - **Trend:** Enhanced focus on customer integration post-COVID, indicating a greater emphasis on aligning with customer needs.
8. **Supplier Integration**
    - **During COVID:** High focus with a peak frequency of 324.
    - **Post COVID:** Increased focus with a peak frequency of 455.
    - **Trend:** Increased focus on supplier integration post-COVID, reflecting a strengthened emphasis on integrating suppliers into the supply chain.
9. **Internal Integration**
    - **During COVID:** High focus with a peak frequency of 417.
    - **Post COVID:** Reduced focus with a peak frequency of 321.
    - **Trend:** Slight decrease in emphasis on internal integration post-COVID, suggesting a shift in focus.
10. **Firm Resilience**
    - **During COVID:** High focus with a peak frequency of 427.
    - **Post COVID:** Decreased focus with a peak frequency of 316.

- **Trend:** Reduced focus on firm resilience post-COVID, reflecting a possible stabilization after the initial pandemic crisis.

11. **Information Complexity**
    - **During COVID:** High variability with peak frequency of 211.
    - **Post COVID:** Increased focus with peak frequency of 442.
    - **Trend:** Increased focus on managing information complexity post-COVID, reflecting an ongoing need to handle complex information.
12. **Supply Chain Orientation**
    - **During COVID:** High focus with a peak frequency of 338.
    - **Post COVID:** Decreased focus with a peak frequency of 43.
    - **Trend:** Significant decrease in focus on supply chain orientation post-COVID, reflecting a shift to other priorities.
13. **Information Management Capabilities**
    - **During COVID:** High variability with peak frequency of 341.
    - **Post COVID:** Increased focus with a peak frequency of 442.
    - **Trend:** Continued and improved emphasis on information management capabilities post-COVID.
14. **Supply Chain Management Strategies**
    - **During COVID:** High focus with a peak frequency of 340.
    - **Post COVID:** Decreased focus with a peak frequency of 257.
    - **Trend:** Reduced focus on supply chain management strategies post-COVID, indicating a shift in strategic priorities.
15. **Risk Management Capabilities**
    - **During COVID:** High variability with peak frequency of 291.
    - **Post COVID:** Continued high focus with a peak frequency of 285.
    - **Trend:** Consistent focus on risk management capabilities post-COVID, reflecting the ongoing importance of managing risks.
16. **Agility**

- **During COVID:** High variability with peak frequency of 315.
- **Post COVID:** Increased focus with a peak frequency of 434.
- **Trend:** Increased emphasis on agility post-COVID, indicating a greater focus on adaptability.

17. **Robustness**
    - **During COVID:** High focus with peak frequency of 283.
    - **Post COVID:** Increased focus with a peak frequency of 446.
    - **Trend:** Enhanced focus on robustness post-COVID, reflecting a strong commitment to building organizational strength.
18. **Supply Chain Performance**
    - **During COVID:** High focus with peak frequency of 262.
    - **Post COVID:** Increased focus with a peak frequency of 277.
    - **Trend:** Continued and increased focus on supply chain performance post-COVID, indicating a sustained emphasis on efficiency and effectiveness.

Comparison of Trends

1. **Focus Increase:** Areas such as procurement, warehousing and logistics, customer integration, supplier integration, and information management capabilities show an increased focus post-COVID, reflecting strategic shifts towards improving these areas in the post-pandemic environment.
2. **Decreased Focus:** Areas like digital technology, supply chain orientation, and internal integration show a decreased focus post-COVID, suggesting a reallocation of priorities or stabilization after the initial pandemic response.
3. **Stability in High Focus:** Risk management capabilities and agility show a consistent high focus, indicating ongoing importance in these areas despite fluctuations in other aspects.
4. **Enhanced Focus on Robustness and Performance:** Post-COVID, there is a noticeable increase in emphasis on robustness and supply chain performance, highlighting a strengthened commitment to organizational strength and efficiency.

Overall, the transition from during COVID to post-COVID reflects a shift from emergency response and high variability to a more stable, focused, and strategic approach in various areas of supply chain management.

5.4 DISSCUSION FROM DURING COVID

Procurement:

- **Key Finding**: Using new technologies like big data analysis, AI, online collaboration tools, and direct digital manufacturing in procurement procedures was a topic on which respondents were highly in agreement throughout the COVID-19 period.

Warehousing and Logistics:

- **Key Finding**: Respondents strongly agreed on the use of visual control systems and big data analysis in warehouse management, indicating a proactive approach to leveraging technology for optimizing inventory management and logistics operations during COVID-19.

Digital Products and Services and Digital Operations Management:

- **Key Finding**: There was a significant agreement among respondents regarding the adoption of digital products and services, as well as digital operations management practices, indicating a strategic focus on digital transformation initiatives to enhance operational efficiency and customer experience during COVID-19.

Digital Technology:

- **Key Finding**: Organizations demonstrated a significant adoption of digital technologies such as Internet of Things, cloud computing, big data analytics, and analytics in operations, reflecting a concerted effort to leverage technology for improving operational processes and decision-making capabilities during COVID-19.

Customer Integration:

- **Key Finding**: Companies emphasized joint planning and collaboration with customers across various stages of the supply chain, indicating a customer-centric approach to supply chain management aimed at enhancing responsiveness and value delivery during COVID-19.

Supplier Integration and Internal Integration:

- **Key Finding**: There was a significant emphasis on joint planning and collaboration with suppliers, as well as internal integration across functional areas within the organization, highlighting the importance of collaboration and alignment in mitigating risks and optimizing operational performance during COVID-19.

Supply Chain Management Strategies:

- **Key Finding**: Companies employed various supply chain management strategies such as flexible supply base approaches, buffer stock maintenance, operational buffers, postponement tactics, adaptable transportation strategies, and Lean and Just-in-Time methods to enhance supply chain resilience and responsiveness during COVID-19.

Risk Management Capabilities:

- **Key Finding**: Organizations demonstrated strong risk management capabilities through the presence of dedicated risk management teams, utilization of risk analysis tools, implementation of supportive methods, and proactive risk monitoring practices, underscoring the importance of proactive risk management in ensuring business continuity and resilience during COVID-19.

Overall Interpretation:

- **Key Finding**: Across all domains of procurement, operations, technology adoption, integration with customers and suppliers, supply chain management strategies, and risk management capabilities, organizations displayed a proactive approach to adapting to the challenges posed by the COVID-19 pandemic. There was a significant emphasis on leveraging technology, collaboration, agility, and risk mitigation strategies to ensure operational continuity, resilience, and responsiveness in the face of uncertainties and disruptions.

Table 5. 1:Key Findings Table during Covid-19

Aspects	**Key Findings**

Procurement	Significant agreement on utilizing advanced technologies for procurement processes during COVID-19.
Warehousing and Logistics	Strong emphasis on using visual control systems and big data analysis in warehouse management.
Digital Products and Services, Digital Operations Management	Significant adoption of digital technologies for enhancing operational efficiency.
Digital Technology	Substantial adoption of Internet of Things, cloud computing, big data analytics, and analytics in operations.
Customer Integration	Emphasis on joint planning and collaboration with customers to enhance responsiveness.
Supplier Integration, Internal Integration	Significant focus on collaboration with suppliers and internal integration across functional areas.
Supply Chain Management Strategies	Utilization of various strategies such as flexible supply base approaches, buffer stock maintenance.
Risk Management Capabilities	Strong risk management capabilities demonstrated through dedicated teams, risk analysis tools usage.

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

5.5 DISCUSSION FROM POST COVID

Unprecedented interruptions to supply networks occurred after the COVID-19 pandemic, revealing weaknesses and stressing the critical need for resilience. Recognising how supply chain tactics affect resilience is critical for businesses to succeed in the post-pandemic age. Significant results across several aspects of supply chain management are shown by the results of the one-sample test analysis.

Part A: Procurement: Post-COVID-19, significant adoption of digital technologies is observed in procurement processes. Big data analysis and artificial intelligence are extensively used for supplier forecasting and decision-making, with mean differences of 2.167 ($t = 36.618$, $df = 509$, $p < .001$) and 2.776 ($t = 49.265$, $df = 509$, $p < .001$) respectively. Digital collaboration systems and direct digital manufacturing with IoT integration have streamlined procurement operations, with mean differences of 2.822 ($t = 50.676$, $df = 509$, $p < .001$) and 2.425 ($t = 39.144$, $df = 509$, $p < .001$) respectively.

Part A: Warehousing and Logistics: In warehousing and logistics, visual control systems and big data analysis play crucial roles. Mean differences of 2.631 ($t = 45.074$, $df = 509$, $p < .001$) and 2.567 ($t = 44.769$, $df = 509$, $p < .001$) respectively indicate their importance in optimizing inventory management and traffic operations post-COVID-19.

Part A: Digital Operations Management & Digital Business Model: Digital operations management, including digital manufacturing, has seen significant adoption, with a mean difference of 2.718 ($t = 46.430$, $df = 509$, $p < .001$). Similarly, digital business models like mass customization and open innovation have become prevalent, with a mean difference of 2.533 ($t = 43.146$, $df = 509$, $p < .001$), enabling organizations to adapt to dynamic market demands post-COVID-19.

Part B: Digital Technology: Post-COVID-19, IoT implementation, cloud computing adoption, and utilization of big data and analytics tools have become prominent in operations. Mean differences of 2.375 ($t = 40.565$, $df = 509$, $p < .001$), 2.110 ($t = 37.092$, $df = 509$, $p < .001$), and 2.425 ($t = 40.122$, $df = 509$, $p < .001$) respectively indicate their contributions to data-driven decision-making and performance optimization.

Part B: Customer Integration & Supplier Integration: Collaborative planning and information sharing with customers and suppliers have strengthened post-COVID-19. Mean differences of 2.341 ($t = 38.486$, $df = 509$, $p < .001$) and 2.473 ($t = 40.467$, $df = 509$, $p < .001$) respectively indicate improved demand visibility and supply chain synchronization.

Part B: Internal Integration: Internal integration across functional areas has improved responsiveness within organizations post-COVID-19. Mean differences of 2.869 ($t = 56.626$, $df =

509, p < .001), 2.112 (t = 41.925, df = 509, p < .001), and 2.504 (t = 46.787, df = 509, p < .001) respectively reflect optimized resource utilization and operational excellence.

Part C: Supply Chain Management Strategies: Flexible supply base approaches and proactive risk management have become paramount in ensuring supply chain resilience post-COVID-19. Mean differences of 2.555 (t = 45.184, df = 509, p < .001) and 2.533 (t = 43.146, df = 509, p < .001) respectively indicate their contributions to agility and responsiveness in the supply chain.

Part C: Risk Management Capabilities: Proactive risk management practices, including dedicated risk control personnel and utilization of risk analysis tools, have been instrumental in mitigating supply chain risks post-COVID-19. Mean differences of 2.892 (t = 91.550, df = 509, p < .001) and 2.931 (t = 71.643, df = 509, p < .001) respectively highlight their role in ensuring business continuity and adaptability to changing circumstances.

Table 5. 2:Key Findings Table during Post Covid-19

Aspects	**Key Findings**
Part A: Procurement	Significant adoption of digital technologies (e.g., big data analysis, AI) for supplier forecasting and decision-making post-COVID-19. Digital collaboration systems and direct digital manufacturing with IoT integration have streamlined procurement operations.
Part A: Warehousing and Logistics	Utilization of visual control systems and big data analysis in optimizing inventory management and traffic operations post-COVID-19.

Part A: Digital Operations Management	Adoption of digital operations management, including digital manufacturing, to enhance operational efficiency post-COVID-19.
Part A: Digital Business Model	Prevalence of digital business models (e.g., mass customization, open innovation) to adapt to dynamic market demands post-COVID-19.
Part B: Digital Technology	Prominence of IoT implementation, cloud computing adoption, and utilization of big data and analytics tools in operations post-COVID-19.
Part B: Customer Integration	Strengthening of collaborative planning and information sharing with customers to improve demand visibility post-COVID-19.
Part B: Supplier Integration	Enhanced joint planning and information sharing with suppliers to synchronize supply chains post-COVID-19.
Part B: Internal Integration	Improved internal responsiveness and resource utilization within organizations post-COVID-19.
Part C: Supply Chain Management	Emphasis on flexible supply base approaches and proactive risk management to ensure supply chain resilience post-COVID-19.
Part C: Risk Management Capabilities	Implementation of proactive risk management practices and utilization of risk analysis tools to mitigate supply chain risks post-COVID-19.

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

5.6 DISCUSSION FROM HYPOTHESIS TESTING

Table 5.3

Summary of Hypothesis Testing

Hypothesis	**Analysis Used**	**Result**
H1: Supply chain resiliency significantly impacts the manufacturing sector's performance during the COVID-19 pandemic.	Regression Analysis	Null Hypothesis is Rejected
H2: Supply chain resiliency is significantly important for the manufacturing sector's performance after the COVID-19 pandemic.	Regression Analysis	Null Hypothesis is Rejected
H3: Strategies related to supply chain management significantly impact achieving supply chain resilience during the COVID-19 pandemic in the manufacturing sector.	Regression Analysis	Null Hypothesis is Accepted
H4: Strategies related to supply chain management significantly impact supply chain resilience post-COVID-19 in the manufacturing sector.	Regression Analysis	Null Hypothesis is Rejected

Source: Statistical analysis on questionnaire response - Gaurav Bhardwaj ©

CHAPTER VI SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

6.1. SUMMARY

The research explores the critical role of supply chain resilience in the manufacturing sector, with a particular focus on the disruptions caused by the COVID-19 pandemic. The research aimed to identify effective strategies that companies could adopt to enhance their supply chain resilience, ensuring continuity of operations in the face of unexpected global challenges. The study began by highlighting the vulnerabilities that the pandemic exposed in global supply chains. These included an over-reliance on a limited number of suppliers, inadequate inventory management practices, and a lack of real-time visibility across the supply chain. These weaknesses were identified as key areas where companies needed to focus their resilience-building efforts.

Through a comprehensive literature review, the thesis examined existing theories and practices related to supply chain resilience, including the integration of digital technologies and the importance of strategic partnerships. The research drew on various case studies and empirical data to assess the effectiveness of different resilience strategies in mitigating the impact of supply chain disruptions. The findings revealed that companies that had invested in proactive resilience measures, such as diversifying their supplier networks, increasing inventory buffers, and adopting advanced digital technologies, were better able to navigate the challenges posed by the pandemic. These strategies not only helped companies maintain operational performance but also positioned them to respond more flexibly to the evolving situation. A key outcome of the research was the identification of digital technologies as crucial enablers of supply chain resilience. Technologies such as the Internet of Things (IoT), big data analytics, cloud computing, and artificial intelligence were shown to significantly enhance the agility and robustness of supply chains. These technologies provided companies with real-time data and advanced analytics capabilities, enabling them to detect disruptions early, make informed decisions, and adapt their operations accordingly.

The thesis also underscored the importance of a tailored approach to building supply chain resilience. It highlighted that while digital technologies are powerful tools, their effectiveness depends on how well they are integrated into the broader supply chain strategy. Companies must consider their specific contexts and challenges when designing resilience strategies, ensuring that these strategies align with their overall business objectives.

The research emphasized the role of cross-functional collaboration and strategic partnerships in enhancing supply chain resilience. Strong collaboration across different functions within an organization, as well as with external partners, was found to be critical in identifying risks, sharing information, and implementing effective mitigation strategies. In conclusion, this thesis has provided valuable insights into the strategies and technologies that can enhance supply chain resilience, particularly in the manufacturing sector. The findings offer practical guidance for businesses seeking to strengthen their supply chains against future disruptions, emphasizing the need for a proactive, integrated, and tailored approach to resilience.

6.2 MANAGERIAL IMPLICATION

In addition to adding to our theoretical knowledge of supply chain resilience, this research provides manufacturing organisations with useful practical implications. These suggestions aim to make the supply chain more resilient by making it more agile, more integrated, and more tech-savvy. In order to provide managers with practical insights, the following discussion expands upon these points and goes into further depth.

Enhancing Supply Chain Agility and Integration

Improving supply chain integration and agility is a key piece of advice for managers. With demand swings and unexpected interruptions happening all the time in today's industry, agility is key. If they want to be agile, managers need to make sure their supply chains can adapt with the times. To quickly adapt to fluctuating consumer demand, businesses may, for instance, need to adjust delivery windows or ramp up or down production. Working closely with partners in the supply chain is essential for achieving this level of agility. Businesses may improve their ability to foresee and react to changes in the market and other disruptions by exchanging pertinent data and keeping lines of communication open.

Supply chain integration is inherently related to improving supply chain agility. When a company's supply chain partners and the company itself are well-integrated, real-time data flows without a hitch. since of this information flow, the supply chain as a whole is more resilient since all participants can respond to interruptions in a coordinated and effective manner. Supervisors should make it a top priority to increase supply chain openness and visibility if they want to reach this degree of integration. Achieving this may be achieved by establishing shared objectives and coordinating approaches to risk mitigation. Supply chain partners may communicate vital information more easily via regular meetings and common digital platforms like cloud-based solutions. By following these procedures, you can be confident that everyone involved is on the same page and can work together to overcome any obstacles.

Strengthening Supply Chain Resilience for Improved Operational Performance

Improving operational performance is only one benefit of a resilient supply chain, which goes beyond just being able to resist interruptions. To better adjust and realign their supply networks, organisations should concentrate on resilience skills like integration and agility. Products are better, service is better, and on-time delivery is more dependable as a result of this flexibility. Managers should consider supply chain resilience a strategic asset that affects their company's capacity to satisfy customers and stay competitive.

Leveraging Digital Technologies to Enhance Supply Chain Resilience

To further fortify supply chain resilience, the report stresses the need of investing in and utilising digital technology. Digital technologies are essential for maximising the positive effects of supply chain integration on resilience. Cloud computing, tracing and tracking technologies, and big data analytics are all part of this category. By facilitating the real-time interchange of information across production and delivery processes, cloud computing, for instance, enhances supply chain visibility and connectedness. Businesses that use these technologies may see improvements in operation monitoring, disruption prediction, and the ability to make rapid, informed decisions.

The capacity of big data analytics to automate the examination of large volumes of data and hence aid in decision-making is particularly noteworthy. For instance, supply chain choices like optimising inventory levels or lowering delivery lead times may be informed by big data analytics, which can assist discover trends and patterns. Better operations and a stronger supply chain are possible outcomes of these realisations.

When deploying digital technology, managers should also consider the costs and benefits. It is critical to make sure the advantages of adopting these technologies do not exceed the costs, even if they may greatly improve supply chain resilience. If managers want to know which technology will work best for their company, they need weigh the costs and benefits. This method strengthens the supply chain and guarantees that investments in digital technology boost the bottom line.

6.3. RECOMMENDATION FOR FUTURE RESEARCH

The findings of this study have significantly contributed to the understanding of supply chain resilience, particularly within the manufacturing sector during the COVID-19 pandemic. However, the dynamic nature of global supply chains and the ongoing evolution of technological and environmental factors highlight the need for further research in several areas. This section provides recommendations for future research to build on the insights gained from this study and address some of the limitations that have been identified.

While this research has focused on the manufacturing sector, future studies could broaden their scope to include other industries, such as retail, healthcare, and hospitality. Each sector is likely to face distinct challenges regarding supply chain resilience, which may necessitate different strategies and approaches. For example, the healthcare sector, which has been critically impacted by the pandemic, may benefit from studies that explore how supply chain resilience can be enhanced to prevent disruptions in the delivery of essential medical supplies and services. Similarly, the retail sector, with its complex network of suppliers and fluctuating consumer demands, presents a unique environment where the principles of supply chain resilience could be tested and refined. Investigating these sectors would not only enhance the generalizability of existing theories but also provide industry-specific insights that could guide practitioners in those fields.

In addition to expanding the industry focus, future research should consider the value of longitudinal studies. The current research provides a snapshot of how supply chain resilience strategies were deployed in response to the COVID-19 pandemic. However, there is a need to understand how these strategies evolve over time and how they impact operational performance in the long run. Longitudinal studies could track the implementation and effectiveness of resilience strategies over several years, providing insights into their sustainability and long-term benefits.

Such research could reveal whether the measures taken during the pandemic have lasting effects on supply chain operations or if they need continuous adaptation to remain effective. Furthermore, this approach could help identify which strategies are most resilient over time, offering valuable guidance for businesses looking to fortify their supply chains against future disruptions. Another critical area for future research is the role of emerging digital technologies in enhancing supply chain resilience. The integration of technologies such as artificial intelligence (AI), blockchain, and the Internet of Things (IoT) in supply chain management is increasingly recognized as a key factor in building more resilient systems. However, there is still much to learn about how these technologies can be leveraged to prevent and mitigate disruptions. Future research could explore how AI can be used to predict supply chain risks and automate response strategies, or how blockchain can ensure transparency and traceability across the supply chain, reducing the likelihood of disruptions due to fraud or mismanagement. Moreover, the IoT's ability to provide real-time data across various points in the supply chain could be examined in terms of its potential to enhance visibility and agility, thereby contributing to overall resilience. Understanding these technologies' full potential and limitations is crucial as businesses increasingly rely on them to navigate complex supply chain challenges.

The COVID-19 pandemic has underscored the vulnerability of global supply chains to large-scale disruptions, but it is not the only threat on the horizon. Future studies should explore the impact of other global disruptions, such as geopolitical conflicts, climate change, and economic crises, on supply chain resilience. Geopolitical tensions, for example, can lead to sudden trade restrictions or sanctions, which can severely impact global supply chains. Climate change, with its potential to cause extreme weather events and alter production conditions, poses a long-term risk that supply chains must adapt to. Economic crises, like recessions or financial market collapses, can disrupt supply and demand patterns, affecting the stability of supply chains. Research in these areas would provide a more comprehensive understanding of the various factors that can disrupt supply chains and how businesses can prepare for them. Additionally, it would help identify strategies that are effective across different types of disruptions, thereby enhancing the robustness of supply chain management practices. Cross-cultural studies present another rich area for exploration. The management of supply chain resilience can vary significantly across different cultural and regulatory environments, especially for multinational companies operating in diverse regions. Future research could compare how supply chain resilience is approached in different countries, taking into account varying levels of economic development, regulatory frameworks, and cultural attitudes towards risk. For instance, supply chain strategies that are effective in highly regulated environments may not be directly transferable to regions with less stringent regulations or different cultural attitudes toward business continuity and risk management. By understanding these differences, companies can tailor their resilience strategies to be more effective in specific contexts, thereby improving their global supply chain management.

The intersection of supply chain resilience and sustainability is an area ripe for future research. As businesses increasingly focus on sustainability, understanding how resilient supply chains can also contribute to environmental and social sustainability goals is essential. Future studies could explore how strategies designed to enhance supply chain resilience can be aligned with efforts to reduce environmental impact, such as minimizing waste, reducing carbon emissions, and promoting ethical sourcing practices. This research could also examine how resilient supply chains contribute to social sustainability, such as by ensuring fair labor practices and supporting local communities. By linking resilience with sustainability, businesses can develop more holistic strategies that not only protect their operations but also contribute to broader societal goals.

Further research is needed to explore the relationship between supply chain agility and resilience. While agility and resilience are often discussed together, they are distinct concepts that interact in complex ways. Agility refers to the ability to quickly adapt to changes, while resilience involves the capacity to recover from disruptions. Future studies could examine how these two concepts complement each other and contribute to overall supply chain performance. For example, research could investigate whether agile supply chains are inherently more resilient or if there are trade-offs between the two. Understanding this relationship would help businesses design supply chains that are not only agile but also resilient, ensuring they can respond to immediate challenges while maintaining long-term stability

Limitation of Study

- The research is limited to the manufacturing sector, which may restrict the generalizability of the findings to other industries. Supply chain dynamics and resilience strategies can vary significantly across sectors, such as healthcare, retail, and hospitality, which were not explored in this study.
- The study primarily focuses on the impact of supply chain resilience within a specific geographical region. This could limit the applicability of the results to global contexts, where different regulatory, economic, and cultural factors may influence supply chain management practices.
- The research provides a snapshot of supply chain resilience during and after the COVID-19 pandemic but does not account for long-term trends or the evolution of resilience strategies over time. A longitudinal approach could offer deeper insights into the sustainability and effectiveness of these strategies.
- While the study acknowledges the role of digital technologies in enhancing supply chain resilience, it does not deeply investigate the specific impacts of emerging technologies like AI, blockchain, and IoT. This limits the understanding of how these technologies can be leveraged to further improve resilience in diverse supply chain contexts

Future Scope of Study

The future scope of this study includes expanding research to different sectors and regions to gain broader insights into supply chain resilience. Longitudinal studies could track changes over time, while exploring emerging technologies like AI and blockchain could enhance understanding of technological impacts. An interdisciplinary approach and the development of resilience measurement models would offer deeper analysis, and studying the influence of government policies could provide valuable guidance for both policymakers and industry leaders in strengthening global supply chains.

6.4. CONCLUSION

The COVID-19 pandemic has fundamentally reshaped global supply chains, revealing vulnerabilities and pushing businesses to adopt resilience strategies at an unprecedented pace. This thesis has explored the intricate relationship between supply chain resilience, digital technologies, and operational performance in the manufacturing sector. The conclusions drawn from this study not only highlight the critical role of resilience in sustaining business operations during disruptions but also underscore the transformative impact of digital technologies in enhancing supply chain agility and robustness.

The research has shown that supply chain resilience is not merely a reactive measure but a proactive strategy that can significantly bolster a company's ability to withstand and recover from disruptions. The manufacturing sector, with its complex and interdependent networks, has been particularly exposed to the shocks of the pandemic. However, companies that had already invested in resilience-enhancing strategies, such as diversifying their supplier base, increasing inventory buffers, and adopting digital technologies, were better positioned to navigate the crisis. These strategies have proven to be essential in maintaining continuity of operations, managing supply chain risks, and meeting customer demands in a volatile environment.

One of the key findings of this study is the pivotal role of digital technologies in strengthening supply chain resilience. The adoption of technologies such as the Internet of Things (IoT), cloud computing, big data analytics, and artificial intelligence has been accelerated by the pandemic, transforming how companies manage their supply chains. These technologies have enabled real-time monitoring, improved decision-making, and enhanced collaboration across the supply chain, all of which are crucial for responding swiftly to disruptions. For instance, IoT has provided companies with greater visibility into their supply chains, allowing them to track shipments, monitor inventory levels, and identify potential bottlenecks before they escalate into significant problems. Similarly, cloud computing has facilitated remote collaboration and data sharing, ensuring that teams can continue to work together effectively even when physical offices are closed.

Moreover, big data analytics has played a vital role in enabling companies to make informed decisions based on real-time data. During the pandemic, companies that leveraged big data were able to optimize their supply chain operations by predicting demand fluctuations, identifying alternative suppliers, and optimizing production schedules. This ability to rapidly analyze and act on data has proven to be a critical factor in maintaining supply chain resilience. Additionally, artificial intelligence has been instrumental in automating complex decision-making processes, such as supplier selection and risk assessment, further enhancing the agility and responsiveness of supply chains.

The findings also suggest that supply chain resilience is not a one-size-fits-all solution but rather a tailored approach that must be adapted to the specific needs and context of each company. While digital technologies are a powerful enabler of resilience, their effectiveness depends on how they are integrated into the overall supply chain strategy. Companies must carefully assess their unique challenges and opportunities and design resilience strategies that align with their business objectives. For example, while some companies may benefit from investing in advanced technologies, others may find that simpler solutions, such as improving supplier relationships or increasing inventory levels, are more effective in enhancing their resilience.

Furthermore, the study highlights the importance of cross-functional collaboration in building supply chain resilience. The pandemic has demonstrated that supply chain disruptions are not isolated events but rather complex, interconnected challenges that require a coordinated response across different functions within the organization. Companies that foster strong collaboration between their supply chain, procurement, production, and logistics teams are better equipped to identify risks, share information, and implement effective mitigation strategies. This cross-functional approach not only improves operational efficiency but also enhances the overall resilience of the supply chain.

In addition to technological and organizational strategies, the research emphasizes the role of strategic partnerships in enhancing supply chain resilience. The pandemic has underscored the importance of having strong relationships with suppliers, customers, and other stakeholders in the supply chain. Companies that have cultivated strategic partnerships have been able to leverage these relationships to secure critical supplies, share information, and collaborate on joint problem-solving efforts. These partnerships have proven to be invaluable in maintaining supply chain continuity during the pandemic and will likely continue to be a key component of resilient supply chains in the future.

While the research provides valuable insights into the factors that contribute to supply chain resilience, it also acknowledges the limitations of the study. The focus on the manufacturing sector means that the findings may not be fully applicable to other industries, such as retail, healthcare, or logistics, which face different challenges and require different resilience strategies. Additionally, the study's reliance on data collected during the COVID-19 pandemic may limit the generalizability of the findings to other types of disruptions, such as natural disasters or geopolitical conflicts. Future research should explore these areas to provide a more comprehensive understanding of supply chain resilience across different contexts.

In conclusion, this thesis has demonstrated that supply chain resilience is a critical factor in ensuring business continuity and operational performance during times of disruption. The findings highlight the importance of adopting a holistic approach to resilience, one that integrates digital technologies, cross-functional collaboration, and strategic partnerships. As businesses continue to navigate the uncertainties of the post-pandemic world, the lessons learned from this study will be invaluable in guiding the development of more resilient and agile supply chains.

The challenges posed by the COVID-19 pandemic have accelerated the adoption of digital technologies and underscored the need for robust supply chain resilience strategies. However, as the global landscape continues to evolve, companies must remain vigilant and proactive in adapting their resilience strategies to meet new challenges. By doing so, they can not only survive but thrive in an increasingly complex and uncertain world. The insights gained from this research provide a solid foundation for companies looking to strengthen their supply chain resilience and ensure their long-term success in the face of future disruptions.

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