ANALYZING THE INFLUENCE OF SUPPLY CHAIN RESILIENCE ON SUPPLY CHAIN PERFORMANCE: ASSESSING THE MEDIATING AND MODERATING ROLE OF SUPPLY CHAIN VIABILITY AND DIGITALIZATION

By

Waleed Ahmad

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Submitted By: Waleed Ahmad **Registration #** 380-MSMS/IBD/S22

Dr. Akhtar Tanweer _____
Name of Supervisor Signature

Dr. Aijaz Mustafa Hashmi _____
HOD (MS) Signature

Prof. Dr. Faid Gul _____
Dean (FMS) Signature

CANDIDATE DECLARATION FORM

I **Waleed Ahmad** Son of **Iqtidar Ahmad**

Registration # **380-MSMS/IBD/S22** Discipline **Supply Chain Management**

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DEDICATION

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ABSTRACT

The rising technology innovations, COVID-19 epidemic, and geopolitical crises like the conflict in Russia-Ukraine, India-Pakistan and the war between Israel and Palestine are experiencing unprecedented levels of instability and uncertainty in global supply chains. These challenges have highlighted the critical need for resilience and viability within supply chains to ensure sustainable performance and competitive edge in the constantly changing global environment. This study investigates into the dynamics of supply chain resilience, viability, and digitalization, focusing on their collective impact on the performance of the electrical electronics manufacturing industry in Pakistan. Specifically, it examines how supply chain resilience directly influences performance, the mediating role of supply chain viability between resilience and performance, and the moderating effects of digitalization on these relationships. Employing a deductive, quantitative, cross-sectional survey approach, data was collected from 47 major electrical electronics manufacturing firms in Pakistan using structured questionnaires, which was then filled from each manager across electrical and electronics manufacturing firms. The electrical and electronics manufacturing firms represent the unit of analysis in this study, providing insights from a broad spectrum of experiences and perspectives within the industry. This research is to fill significant gaps in the literature by integration of supply chain resilience, viability, and digitalization into a coherent framework, the aim of this research is to close significant gaps found in the body of current knowledge. This provides valuable insights that can assist organizations in an increasingly volatile global market to improve their adaptability and recovery mechanisms. The findings are expected to not only enhance the understanding of supply chain dynamics but also support Pakistani enterprises in boosting their operational efficiency and resilience in the face of global economic and political crisis.

Keywords: Resilience, Supply chain viability, Digitalization, Artificial intelligence, Internet of things.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
SCR	Supply Chain Resilience
SCV	Supply Chain Viability
SCP	Supply Chain Performance
SCM	Supply Chain Management
IOT	Internet of Things
HMPV	Human Metapneumovirus
WHO	World Health Organization
SCD	Supply Chain Digitalization
RBV	Resource Based View

CHAPTER 1

INTRODUCTION

1.1 Background of the Topic

In this highly volatile present-day environment where economic instability, consumer behavior, market trends, political crises and constantly shifting demands of customers are all major issues affecting supply chain networks, global supply chain networks are challenged (Sultana et al., 2024; İncekara & İncekara, 2024). The list of such challenges is threatening. Firms strive to ensure that they respond to the changes by a supply chain management undertaking new challenges. The recent significant shocks, including the current war between Israel and Palestine, the current crisis in Ukraine, COVID-19 pandemic, along with the wars between India and Pakistan, recent flood 2025 in Punjab and KP Pakistan, have increased the uncertainty, and instability of world trade and transport (Sarwar & Rye, 2025; Luo et al., 2025). With such unexpected failures, the supply chains have been revealed as having a few weaknesses. According to this study, it is pressing to ensure that firms increase their operational flexibility and strategic resilience (Durach et al., 2024). It has then lead to supply chain viability becoming a scalding topic among organizations that are striving to survive and recover amidst the unforeseen organizational breakages. The companies should then consider strategies that will enable it to stay productive in its operations, decrease risks, as well as be capable of navigating through the supply chain easier (Ruel et al., 2024; Sultana et al., 2024). Shortly, the companies are to handle the effect of the increased frequency, severity and volatility of, the supply chain crisis.

The viability of supply chains is as the recent change is justified by the proactive steps of supply chain improvement and ensuring survival in the less stable global environment in the long term (Ivanov & Dolgui, 2020). To cope with disruptions, the organizations should enhance their operating models, recalibrate their

production systems and modify and alter their supply chain activities. This flexibility will allow the firms to react to the abrupt demands adequately enough to continue with the functioning, and alleviate the effects of the external shock (Agrawal et al., 2024).

Companies that make decisions early in their supply chain approach development are in a better position to overcome shortages and sickness in future (Hajarath & Vummadi, 2024). Increasing the resilience of supply chain is essential in a high level in order to enable firms to respond to risk, formulate response strategies and remove vulnerabilities as proposed by academic researchers and corporate leaders (Chowdhury et al., 2024; Mohammed et al., 2025). Resilient supply chains help a company mitigate the unusual disasters and guarantees increased efficiency in investment of business processes. That will ensure a long era of growth and competitiveness in a highly volatile international market (Shekarabi et al., 2025; Lin & Li, 2024). The capability of properly addressing disruptions is typically a key strategic ambition of purchasers to build rather agile and robust supply-webs (Li et al., 2022; Queiroz et al., 2022).

Generally defined, the resilience can be described as the capacity to identify the threats that may arise, to make the strategic plans in the case of the unforeseen occurrence, to respond to the disrupters and consequently to restore what has been done. This aptitude or skill can demonstrate the ability which demonstrates the rudimentary skill of carry through and permanence in uncertainties. In chain of supply, resilience involves more than capacity to limit immediate losses and absorb shocks. Adaptability to control operational impact, react with rapidity, and implement control solutions and the ability to restore or even enhance operational reliability after disruptions is also components of resilience in the supply chain. To reduce the adverse impact, preemptive risk management is necessary, and supply chain process urgently needed rapid changes (Shekarabi et al., 2025). Not only do organizations that create a robust supply chain have further chances to recover from the events but also improve their overall efficiency, competitiveness, and sustainability in the environment that is increasingly becoming erratic on a global scale (Singh et al., 2019).

Many recent events, including political unrest in Pakistan, India-Pakistan tension, COVID-19, Russia-Ukraine war and crisis in Palestine, and flood 2025 in

Pakistan have added to the uncertainty not only in Pakistan but also throughout worldwide supply chains (Sarwar & Rye, 2025). The unexpected shocks of the past such as COVID-19 have led to the interesting field of research on viability. (Ivanov, 2020) defines supply chain viability as the ability of a company to stay strong and sustain over an extended period of time in an always changing environment. This calls on the business to reorganize its organizational framework to create long-lasting effects. The results of a supply chain viability study indicate that companies who have the means to absorb, adapt to disturbances by quick redesign of supply chain infrastructure are more likely to keep their competitive edge (Faruquee et al., 2021). The sizzling rise in digitalization has elevated the urgency of the supply chain integration and the application of digital technology.

Nowadays, in real life, any person can agree that the growing globalization of the markets and their unpredictability demand a mixture of many technologies including artificial intelligence (AI), Internet of things (IoT), and blockchains (Li et al., 2025; Irfan et al., 2024). The importation of these shinning digital tools into the organizations boosts the supply chain resilience, viability, efficiency and agility of the organizations (Ali et al., 2024). This is the relevance of the paper because daily the business world is turning tremendously volatile and unpredictable. Such technology aids the enterprises in dealing with a volatile business environment. In a nutshell, they improve the supply chain management, operations and contribute to a smarter decision making process (Ho et al., 2022). Those companies which already have implemented the digital supply-chain approach and are promoted by effective digital technologies are likely to possess the competitive advantage over the competitors as the discussion of the work of supply-chain digital transformation reveals (Zhang et al., 2023; Ali et al., 2024).

The latter is enormous in the market that it is turning even more chaotic every year. Using the newest digital tools like AI, IoT, blockchain, in their daily work help companies become more flexible, can take less time to conclude the decision and enhance the effectiveness of their supply-chain systems (Alheet & Attiany, 2025). Through this plan the significance of such tools in order to compete in the contemporary competitive business environment has been brought out. They contribute to the easing of the digitalization process that enables simplification of

logistics, minimized risks and alterations to deal with market changes (Khan et al., 2021).

Digitalization of the companies can accomplish more than huge potential, yet it is not always fulfilling the performance expectations of the companies. Even with all the benefits associated with digital technologies (e.g., agility, better decision-making system, higher productivity), many businesses are still unable to enjoy all of the associated benefits (Atieh et al., 2025). In numerous instances, various issues that may include the lack of proper implementation strategies, unhappiness towards change, technical incompetence, and problems with integration hold back the successful adoption of digitalization. This makes it difficult for companies to realize the advantages of digitalization (Rodríguez & Smith, 2024). This leads to performance fluctuations and limits their capacity to completely embrace the opportunities offered by digital transformation (Yu et al., 2023).

The concept of viability is only recently emerging; therefore, less data exists on this topic arguing in favor of greater research. The supply chain viability is extremely promising with respect to enhancing resilience, adaptation, and long-term sustainability. It has been largely neglected in terms of its role in the system of digital supply chains (Ruel et al., 2021). The full potential of the digitalization performance needs to be revealed through the detailed analysis of this concept. Supply chain viability analysis in the light of digital transformation may give very helpful ideas regarding how workplaces might make maximum out of their strategies to enhance their operation efficiency and manage model environmental uncertainty (Ivanov, 2021). Researchers and business organizations increasingly becoming aware of the pressing need to make supply chain management digitalized and resilient to remain operational with adequate efficiency and competitiveness. Though individuals are becoming more aware of these problems the actual process and dynamic issue are largely unknown. In particular, the extant literature overlooks such mediating effect of supply chain viability and moderating effect of digitalization between resilience and supply chain performance. Therefore, this is the gap in the research.

1.2 Research Gap

This study shall be able to fill gap through a systematic analysis of the interconnection between supply chain resilience, viability and digitalization. Findings

on this study will unveil how all these aspects work together to establish a total operation of supply chains in firms. The study aims at presenting substantial new information that could guide companies in achieving sustainable supply chain strategies as far as long term sustainability, flexibility and higher efficiency is concerned. Answering the interplay among these factors will help the companies achieve a higher output from supply chain.

This study is focused on providing meaningful inputs and recommendations to firms to become resilient in more unpredictable and uncertain world, as well as grow and survive. The study is focusing on to the industry of the electronic and electrical market in Pakistan. External influences and the threat of external disruptions are also extremely sensitive to the electric and electronics manufacturing sector in Pakistan due to the reliance on importing raw materials. The sector has also been hit most relative to other industries following the severe calamities like the wars between countries like Israel- Palestine, calamities and outbreak of the COVID period, political, and economic crisis.

With these issues, it is urgent to find a way to conduct more research on the manufacturing industry of electrical and electronic products in order to improve on their understanding of the weak points in their supply chain, and how to reduce the risks it is exposed to. The study includes the literature with the already available body of knowledge and it also makes the formulation of adequate solutions imperative in order to ensure that the performance and sustainability of supply chains is improved. The evaluation of the relationship between the variables and the strength and sustainability of the supply chain in regards to being influenced by these challenges will be helpful in achieving the desired result. The study will be interpreted in a manner that will help the firms who would like to do a better job in developing their supply chain management systems, resilience to disruptions and confront a dynamic economic environment with confidence and success.

1.3 Problem Statement

The instability in global supply chains is unprecedented due to changing customer demands, geopolitical conflicts, pandemics, disasters related to climate change and economic uncertainty. The Russia-Ukraine conflict, the war between Israel and Palestine, the COVID-19 pandemic, and the natural disasters have revealed

structural weaknesses in supply chains across the world. Pakistan has been a very sensitive country since it has faced extreme weather conditions, earthquakes, floods and severe droughts over the last decades, which have greatly affected the economic activity and supply chain infrastructure.

Electrical and electronics manufacturing industry in Pakistan is particularly vulnerable to such interruptions due to the high reliance of this sector on imported raw materials and components, mostly of Chinese and other origin. Any interruption or delay in imports has a direct impact on continuity of production, efficiency of operations and supply chain performance. These issues demonstrate the limitations of the conventional supply chain management methods that are rather short-term in nature and are insufficient to achieve long-term sustainability and flexibility.

Supply chain viability (SCV) has been introduced as a more holistic approach in response to long term disruptions. SCV is not limited to resilience and focuses on the capacity of a supply chain to persist, adapt to long-term disruptions, and sustain performance over time (Ivanov, 2020). With global supply chains becoming more complex and unpredictable, SCV is important to manage both short-term shocks and long-term structural changes (Ivanov & Dolgui, 2020).

Despite growing interest, limited empirical research has been conducted to examine the combined of supply chain resilience, digitalization, and viability. Although some previous research studies has focused on resilience and digitalization separately, the processes by which digitalization and resilience together contribute to supply chain viability and performance are well explored, especially in developing economies (Ivanov et al., 2021; Zouari et al., 2021). This gap needs to be addressed because supply chain viability has been demonstrated to facilitate sustainable performance in the face of long term uncertainty (Zhao et al., 2023). Thus, the purpose of the study is to investigate the role of resilience, digitalization, supply chain viability, and performance to enhance academic knowledge and theoretical implications to organizations to survive in unstable environments.

1.4 Research Objectives

1. To examine the direct impact of supply chain resilience on supply chain performance in the context of the Pakistani market.

2. To investigate the supply chain viability as a mediator between resilience and supply chain performance.
3. To investigate the level of digitalization moderates the relationship between supply chain resilience and supply chain viability.
4. To examine the combined effect of digitalization, supply chain resilience, and viability to overall supply chain performance.

1.5 Research Questions

1. How does resilience relate to supply chain performance in the context of the Pakistani market?
2. How does the supply chain resilience and performance get mediated by supply chain viability?
3. To what extent, supply chain resilience and viability moderated by digitalization?
4. What effect do resilience, supply chain viability, and digitalization have together on supply chain performance?

1.6 Significance of the Study

The study is noteworthy because supply chains are becoming more exposed to disruptions at the global level, such as pandemics, geopolitical wars, natural disasters, as well as economic uncertainties, especially in developing economies such as Pakistan. The recent occurrences such as the COVID-19 pandemic and the political conflicts in Pakistan have revealed structural weaknesses within supply chains. In this framework, it is relevant and crucial to investigate the relationship between supply chain resilience, viability, and digitalization.

According to industrial and managerial perspective, the study would be most useful in the electrical and electronics manufacturing industry in Pakistan that is highly reliant on the imported raw materials and components. Any break in imports has direct impact on continuity in production, operational efficiency and performance in exports. This study will assist companies to increase flexibility, and become more competitive in the long-run through the empirical study of the digitalization as mediating the relationship between supply chain resilience, viability and performance.

The study provides a good implication to the economic stability and development of the industries in the country. Electrical and electronics industry is an important sector in the Pakistani economy. This study can provide insight to policy makers in developing policies that can enhance digitalization and industrial resilience by highlighting the importance of digitalization and viability as a tool to strengthen supply chains.

Theoretically and academically, the research study will fill a significant gap in the literature of supply chain management. The role of supply chain resilience, supply chain viability, and digitalization has been analyzed in the previous studies. There has been little empirical research on the combined effects on supply chain performance, especially in emerging economies. Combining these ideas into a single framework, the given study contributes to the current knowledge of supply chain viability and offers a point of reference to future studies.

On the whole, the research study contributes greatly to the work of practitioners, policymakers, researchers as it provides empirical data on how resilience, viability, and digitalization jointly contribute to the performance of the supply chain and sustainability in the developing economy.

CHAPTER 2

LITERATURE REVIEW

2.1 Dynamic Capability Theory

Dynamic capability theory is an extension of the resource-based view theory and was first introduced by (Teece et al., 1997). Since the outside world is constantly evolving (and the economic downturns, wars, new tech breakthroughs, and, most importantly, pandemics like COVID-19 are only the tip of the iceberg), the company must not only have sufficient resources; it must be able to combine them and adapt them in real-time.

Dynamic capability theory focuses on three capabilities including innovative, adaptive and absorptive. Innovative capability is the ability of the firm to create new ideas and transform them into profitable products or services. Adaptive capability is the ability of organizations to reconfigure existing offering to align with dynamic market conditions. Absorptive capability is the skill of identifying new trends, evaluating them, and incorporating them into established organizational practices. The combination of these three becomes the basis of long-term competitiveness in the volatile markets.

The dynamic capability aligned with supply chain resilience. Supply chain resilience is the capacity of a supply network to bounce back after disruption or keep functioning during uncertainty. Consequently, resilience fulfills the characteristics defined in the dynamic capability theory (Pimenta et al., 2022). Companies that track environmental shifts and adjust supply chain activities accordingly demonstrate all three capabilities (Pimenta et al., 2022). Due to that, their competitiveness remains in the long term.

Furthermore, the dynamic capabilities view aligns with the concept of supply chain viability. Dynamic capacities provide a helpful basis for examining how digital transformation influences corporate culture (Schneider & Kokshagina, 2021). (Teece

et al., 1997) claim that these concepts relate to companies' capacity to recognize changes in the market, grab opportunities, and rearrange both internal and outside resources to remain competitive. Digitalization makes it easier to get integrate, and use technology and information resources. This improves an organization's ability to detect, grab, and reorganize resources in response to changing market conditions (Li et al., 2025). As a moderator, digitalization enhances the influence of resilience on supply chain performance by enabling quicker and more efficient responses to disturbances through the use of digital platforms and technology (Ali et al., 2024).

2.2 Supply Chain Resilience

The COVID-19 pandemic was a historic event that severely disrupted supply chain and caused destruction around the world (Queiroz et al., 2022; Ivanov & Dolgui, 2020). The rapidly changing demands of customers, recent flood 2025, COVID-19, and recent political crisis severely effect supply chains in Pakistan and around the globe, as disruption in one area has an impact on the entire supply chain. The web of interrelated global supply chains networks makes them more exposed to risks and uncertainties. A disturbance in one part could have a domino effect, paralyzing the whole supply chain (Nikookar & Yanadori, 2022). Firms were not ready to face geopolitical tensions thus posing a state of uncertainty. These crises have made the underlying vulnerabilities more severe which play a major role in disruption of the availability of raw material, transit of commodities, and the effectiveness of the entire supply chain activities. Such disruptions have been reflected in subsequently increased costs, logistical challenges and delays in manufacturing. This underlines even more the need of companies enhancing their supply chain operations in terms of their resilience, flexibility, and digital transformation (Ivanov, 2021). Resilience in the supply chain (SCR) is emerging to be a critical capacity of companies doing businesses when there are interruptions (Vanany et al., 2021). Resilience in contributing to supply chain supports businesses against their weaknesses so that they recover themselves after overcome by difficulties to enhance the efficiency of the supply chain (Pettit et al., 2013). Business enterprises not only need to being focused on cost reduction but also developing resilience in reaction to uncertainty in the supply chain (Cappelli & Cini, 2020).

Supply chain resilience is a system’s ability to grow and adapt to challenges as well as bounce back from disruptions is a key component of modern supply chain management (Wieland & Durach, 2021). These days, global supply chains are much riskier and more complicated. Therefore, the importance of resilience has increased significantly. Resilient supply chains produce higher consumer value and improved financial performance (Li et al., 2017). Such evidence highlights how important resilience is for handling difficulties and maintaining the efficiency of operations.

Recent studies examine supply chain resilience (SCR) from a capacity perspective. According to (Yu et al., 2019), supply chain resilience (SCR) is the ability of the supply chain to quickly restore or enhance its operations, absorb disruptions, and react to interruptions. A company can manage vulnerability and ensure business continuity by improving its SCR (Vali-Siar & Roghanian, 2022). SCR places an extreme value on responding and recovering capabilities when supply chain encounter unknown risks (Scholten et al., 2020).

Although earlier studies usually considered supply chain resilience (SCR) as one-dimensional, new data show its multidimensional character (Parast, 2022). Different dimensions called for diverse set of tools and resources. According to recent research, SCR has both proactive and reactive thus that is two-dimensional (Llaguno et al., 2022). While reactive capacity is to respond and recover following the occurrence of risk, proactive capability denotes a company's readiness before of a disturbance.

Based on dynamic capability theory, a three dimensional SCR framework comprises proactive and reactive capability as well as quality design of the supply chain (Chowdhury & Quddus, 2017). The question arose how an organization can improve these three capabilities to enhance supply chain resilience. Various elements contribute to the improvement of supply chain resilience, including social capital, human capital, and the cognitive abilities of supply chain managers, among other factors. The identified elements are crucial for enhancing the resilience of the organization's supply chain, including factors such as responsiveness, adaptability, and visibility (Nikookar & Yanadori, 2021).

2.3 Supply Chain Viability

The changing customer's demand, covid-19 pandemic, geopolitical conflicts, and long term disruptions highlight the need to reinforce supply chain viability and resilience. Local and global economy has been particularly affected and creates massive under-supply through the global supply chains that not meet the demand. The COVID-19 pandemic has left many supply chains in the world in disasters as (Araz et al., 2020) point out. A global spread of COVID-19 in early March of 2020 led to quarantines, border closures, and the entire halting of supply chains vital operations and markets. The world declared a global pandemic on March 11, 2020, and the announcement was made by the organization World Health Organization (WHO).

The features of many of their organizations are lean and globalized supply chains that were severely threatened by the coronavirus (Ivanov, 2020). The market of hand sanitizers and facial masks increased significantly and supply was not able to cope with the market. This situation provokes questions of sustainability in the society and market. The other sectors of the economy, including the automotive industry, faced serious losses in terms of demand and supply, which leads to possible bankruptcies, and temporary shutdown of production activity (Harbour, 2020). Apart from covid-19, Pakistan was facing economic instability which resulted in closure of imports in 2022-2023. The manufacturing sectors dependent on imports of raw materials face loss. Such problems demonstrate how little our understanding of SCR is as of today and how much more intensive research is required beyond the traditional supply chains.

The viability concept is one of the interesting areas to conduct research on. Although viability as a concept remains less investigated, on the other hand supply chain resilience has taken the interest of many (Dolgui et al. 2020; Hosseini et al., 2021). The COVID-19 outbreak as well as war between countries shows that in the exceptional cases of disturbance, supply chain resilience to a disruption needs to consider both survivability and viability. To prevent collapses both in supply chains and the market in order to continue the supply of goods and services provision (Ivanov, 2021). Thus, the goal of this study is to increase the sustainability of a typical supply chain and thereby reduce the vulnerability of the same supply chain to future shocks. When firms incorporate viability and resilience, they are in a better position to

adjust to the changes in customer preferences, fast-changing technology, natural disasters and even such critical events like the COVID-19 epidemic (Ivanov, 2021).

Viable supply chains can also help organizations survive and necessarily to excel among turbulence in the ever-changing global market (Ivanov & Dolgui, 2020). This has been made possible since it also takes into consideration other elements; including digitalization, responsiveness, and active risk management in the supply chain (Ivanov, 2021). Conversely, the main objective of supply chain resilience is to react to and recover from unanticipated events causing abrupt interruptions. The supply chain resilience cannot deals with disruptions by events including pandemics, world wars, new technologies, and financial crises. Usually, these result in supply chain inefficiencies, disruptions, and shortages in supplies.

Although SCR aims to restore normalcy as quickly as possible, it does not specifically address the long-term structural changes necessary for sustainable adaptation (Ivanov & Dolgui, 2020). Supply chain viability (SCV) has become more significant than supply chain resilience due to the extent and unpredictability of recent global disruptions. Supply chain viability takes into account how supply chains adapt to present and upcoming difficulties, whereas resilience focuses on short term recovery (Ivanov et al., 2021). This shift in perspective highlights the necessity of reorganizing supply chain systems, reassessing performance standards, and utilizing eco-friendly technologies that will increase output over the longer period.

In today’s supply chain research, the topic of supply chain viability keeps rising to the top. According to (Ivanov, 2020), supply chain viability is "a company's to successfully sustain itself over an extended period of time in a changing environment by redesigning its organizational structures and preparing its long-term financial outcomes.” This definition of supply chain viability emphasizes a specific dynamic ability in view of recent disruptive events, including world wars and the COVID-19 epidemic. The important lesson here is the capacity to continue serving customers despite an abrupt change in the environment. In other words, if a company cannot keep supplying its products or services when circumstances radically shift, its supply chain has failed the viability test (Ivanov & Dolgui, 2020). Essential components of companies’ capacity to fit into unfamiliar environments when changes take place are resilience and viability in the supply chains.

Furthermore, supply chain viability differs from resilience. In a viable supply chain, the system develops in response to disturbances (Ivanov, 2021). Companies trying to meet today's customer needs have to show resilience in their supply chains and guarantee their sustainability. Businesses' ability to thrive in the face of ongoing global conflict and the COVID-19 pandemic cannot be explained by the narrow perspectives of SC resilience, which are restricted to a closed system setting (Ivanov & Dolgui, 2020). Apart from being prepared for disruptions, supply chain viability includes resilience, adaptability, and sustainability.

Establishing a sustainable supply chain by means of production, innovation, re-evaluation of resourcing strategies, and capacity optimization will help businesses survive both during and after long-term uncertainty (Ivanov, 2020). The research addresses resilience, adaptation, and sustainability as components of supply chain viability (Ivanov & Dolgui, 2020).

The concept of viability expands upon the concept of resilience in two primary ways:

1. Resilience is defined as the ability to recover from disturbances, such as natural disasters, and return to a normal condition. Viability refers to the capacity to operate and persist in providing products and services to markets and customers during disruptions and extended crises such as COVID-19, Israel-Palestine war, and long term political instability. This highlights the significance of long-term survival through adaptation and dynamic reconfiguration (Ivanov & Dolgui, 2020).
2. Resilience emphasizes the economic performance of individual supply chains, whereas viability combines resilience with sustainability by incorporating economic and societal components. Viability includes both individual supply chains and the broader interconnected supply chain networks and ecosystems (Ivanov & Dolgui, 2020).

The concept of supply chain viability extends our knowledge, especially with regard to surviving prolonged and unforeseen disruptions. (Ivanov & Dolgui, 2020) argue that “The viability of a system is defined by its properties driven by behavior in connection with structural dynamics. The analysis examines the evolution of systems by balancing disruption and reaction within the framework of an open system. The

viability analysis is focused on long-term sustainability.” Viability is further defined by (Ivanov, 2022) as a "supply chain's ability to adapt to a changing environment by reorganizing its structures and rearranging its operations with long-term consequences."

The recent crises illustrate that the viability perspective has the need to be adopted, and there are possible spheres that can be used to contribute to the field in the future. A review of what has emerged in the theory of supply chain viability is presented in (Ivanov & Keskin, 2023). It made clear the interdependence of global supply chains because the pandemic meant that many firms halted production due to shortages in supply, quarantine restrictions and market shocks (Dolgui et al., 2020; Ivanov, 2020; Li et al., 2021; Park et al., 2022). Such predicament as pandemic, Israeli-Iranian conflict explains why it is important to avoid interruptions in supply chains and markets, preserving the availability of goods and services to meet the demand of customers. To minimize the impact of future threats and ensure long term economic stability, firms and government authorities must develop preventive measures that consider the ever evolving worldwide challenges (Ahmad & Ma, 2020; Ahmad & Afzal, 2020; Hussain et al., 2020).

Thus, developing new thinking to shift the focus of researchers from resilience to viability is essential. Viability enhances supply chain resilience, contributing to survivability during extreme circumstances (Dolgui et al., 2020; Ivanov, 2021). The concept of supply chain viability in extreme situations goes beyond economic goals, highlighting the necessity of maintaining long-term sustainability over time.

2.4 Supply Chain Digitalization

The implementation of digital supply chain systems provides a significant advantage during the era of digital transformation (Ivanov & Dolgui, 2020). Since the COVID-19 epidemic, demand for paperless operations, work from home, and supply chain reorganization has sharply risen. This has accelerated the digitalization of supply chains, enabling businesses to respond swiftly to potential disruptions (Ardolino et al., 2022). Blockchain technology is also having an impact on the food supply chain by enhancing traceability and monitoring throughout the process of production (Rogerson & Perry, 2020). Businesses integrate digital technology with such aspects as skills, corporate culture, and digital strategy as one of the ways of

achieving their goals (Li et al., 2022). There is a rising interest between industry and academia in technological advances in the sphere of supply chain management. Digitalization is the changer of operations and businesses, and it continues to improve their supply chain performance (Hennelly et al., 2020).

Digitalization of the supply chain merely encompasses integration of blockchain, artificial intelligence, and the Internet of Things into a supply chain to render all activities in the chain user-friendly (Colombari el at., 2023). Through the assistance of such tools as smart contracts and intelligent labeling, companies can keep the information regarding the products clean and transparent throughout the process (Zhou et al., 2023).

According to the latest research findings, it is possible to state that higher levels of performance are associated with digitalization greatly. It enhances the concept of supply chain viability, openness, innovation, connectivity, and transparency with digitalization of the supply chain (Culot et al., 2020). Digital tools also improve the efficiency of resources, facilitate green supply chains, and speed up corporate innovation related to the manufacturing aspects (Rossit et al., 2019). To that extent, the digital capabilities increase information exchange, reduce the number of unethical behaviors, as well as reinforce supplier-customer partnership (Zhang et al., 2022). Digitalization is important in the resilience and viability of supply chains.

The mobilization of dynamical capacity by introducing transformations in technology assists companies in increasing the resilience and overall performance of the supply chain. The idea grants the companies practical experience of shock recovery and improvement of daily procedures (Pu et al., 2023). Its advantages become more obvious when sophisticated technology that is associated with Industry 4.0 is employed to strengthen supply chain resilience (Xu et al., 2022). The study sheds light on the digitalization effect on supply chain performance and disruption management, the ability to boost supply chain resilience and viability of supply chain. It further indicates the role of the supply chain interruptions and uncertainty as being regulated more effectively by the means of technological driven strategies (Pu et al., 2023; Xu et al., 2022).

2.4.1 Artificial Intelligence

The definition of artificial intelligence has been through the ups and downs since its emergence in the 1950s and it is only the major happenings that brought the industry back (Baryannis et al., 2019). Within the last two decades, the use of available data and the dilemmas that companies can encounter has returned to interest in a variety of fields (Scholten et al., 2020). Companies are finding out the ways AI will simplify the daily functions to reach their specific objectives.

In other words, artificial intelligence is a network of interconnected computers that has the ability to duplicate human intelligence- performing activities like planning, evaluation, prediction, and suggestion with the aim of resolving business issues (Huang & Rust, 2023). Artificial intelligence enables companies to independently apply design thinking and use its learning powers to get insightful analysis of data. This enables companies to use effective tactics and find supply chain flaws (Wamba & Akter, 2019: Wamba & Queiroz, 2022). AI can be used to ensure the rapid analysis of client expectations, market trends, failure analysis, and supply chains optimization and stimulate innovation through the automation of processes to accelerate product development (Jabbour et al., 2020). Artificial intelligence is visible in many industries such as the manufacturing and e-commerce industries particularly in supply chain management.

As the organizations is facing increasingly difficult operational constraints, resilience in supply chain turned out to be an essential requirement in the conditions of the altered customers demand and the COVID-19 epidemic (Zouari et al., 2021). The customers of the modern business world are demanding more involvement of customized solutions along with supply chain resilience. The growth of AI has enabled customer profile analysis whereby customized products are shipped without adversely affecting safety and privacy thus strengthens the robustness of supply chain (Huang & Rust, 2023). To conclude, it becomes even more important that the role of AI is growing; the organizations that do not implement it in their operations will find it hard to maintain the necessary supply chain performance in the constantly evolving market. There are several Ai applications useable in supply chain management activities in Table 2.1.

Table 2.1 Application of AI to supply chain activities

AI Technology	Application in Supply Chains	Source
Machine Learning	Demand forecasting Vulnerabilities Risk management	Carbonneau, Laframboise, & Vahidov (2008) Gu, Dolan-Gavitt, & Garg (2017) Baryannis, Dani, & Antoniou (2019a)
Expert Systems	Professional contracts Risk management	Shokouhyar et al., (2020) Soleymani & Nejad (2018)
Robotics	Advanced automation Scheduling	Viswanadham (2002) Sadik & Urban (2017)
Natural Language Processing	Supply chain maps Advanced automation	Wichmann et al., (2020) Dash et al., (2019)
Machine Vision	Defective product detection	Benbarrad et al., (2021) Ireri et al., (2019)
Speech Recognition	Demand forecasting	Kilimci et al., (2019) Torres et al., 2020

Note. This table summarizes major AI technologies and their applications in supply chain activities.

2.4.2 Blockchain

Blockchain technology is also a key driver of digitalization. The emergence of blockchain technology in 2008, following its introduction by the launch of Bitcoin, established it as a powerful decentralized platform for managing data and facilitating transactions (Nandi et al., 2021). In addition to its significance in crypto currency, blockchain technology has demonstrated effective applications in multiple business sectors, especially within value chains and supply chains (Narayan & Tidström, 2020; Qahtan et al., 2023; Srivastava & Dashora, 2022). Block chain is also known as ‘distributed ledger technology” tracks digital asset transactions within an IT network. Instead of using traditional centralized systems, it uses distributed databases and

connects them using cryptographic techniques and a consensus mechanism (Bali & Singla, 2021; Lim et., 2021; Min, 2019).

A blockchain is a list of connected blocks with a timeline, a cryptographic signature of the previous block and a record of transactions (Srivastava & Dashora, 2022). On the basis of this data structure, a new block is created during a transaction and associated with prior blocks and added to the distributed ledger (Kouhizadeh et al., 2021). The distributed system of block chains fully employs the absence of central authorities or the middlemen. That assists the majority of participants in checking transactions prior to their documentation (Ozturk & Yildizbasi, 2020). Also, the activity of nodes in the blockchain network is organized in blocks (Apeji & Sunmola, 2020; Vivaldini & de Sousa, 2021). Thus, organizations need to better incorporate block chain technology into supply chain to enhance efficiency.

The block chain technology is capable of enhancing supply chain operations by ensuring that day to day operations in the chain are more transparent, reliable, and coordinated (Ozturk & Yildizbasi, 2020). By storing information on a common and non-modifiable system, all the supply chain partners will have a clear view of the origin of products, their flow and the time of transactions, thereby minimizing mistakes, delays and fraud (Srivastava & Dashora, 2022). Smart contracts, also known as automated agreements, make the process of payments, approvals, and so on faster because they eliminate the need for a lot of manual work and middlemen. Simultaneously, access to correct data in real-time will help achieve improved inventory planning and decision-making (Vivaldini & de Sousa, 2021). Blockchain can assist supply chains to work more effectively and respond to disruptions more quickly by enhancing partners trust and visibility, as well as long-term performance (Apeji & Sunmola, 2020).

The analysis of digitalization goes further in the choice of specific technology to reduce risks. It also involves the incorporation of digitalization in entire framework of supply chain network. Research is the key to learning how the supply chain digitalization can enhance the productivity and supply chain performance of various locations during the emergencies.

2.5 Supply Chain Performance

Organizations frequently use operations performance, often focusing on standard metrics like cost, service, and quality. However, the evaluation and management of supply chain performance pose greater difficulties due to the complex nature of boundary-spanning activities (communication, coordination, collaboration, and negotiation with stakeholders) across the supply chain. With the rising acknowledgment of the benefits associated with strategic relationships in supply chains, there is need for thorough research studies that incorporate specific SC performance metrics. A company, for example, can evaluate supply chain performance by tracking on-time delivery rates, inventory turnover ratios, and supplier lead times (Xu et al., 2022). Examining these indicators will help the company identify areas needing development and enable it to establish close ties with important suppliers to enhance overall supply chain performance (Ardolino et al., 2022).

Traditional financial indicators—such as market share, return on investment, earnings before interest and tax, and sales growth—have been thoroughly examined in existing literature (Cadden et al., 2020). A number of studies indicate that improving integration within supply chains may lead to significant performance enhancements (Cadden et al., 2020). It has also been suggested that businesses evaluate supply chain performance considering non-financial factors including product quality, just in time delivery, and supplier responsiveness.

These steps points out areas for enhancement and provide a comprehensive overview of the overall efficiency of the supply chain. Focusing on both financial and non-financial measures helps companies to create a more complete strategy to supply chain management and finally improve operational success (Ardolino et al., 2022). Therefore, it is recommended that performance indicators for supply chains include elements relevant to the supply chain environment, thereby going beyond traditional operational standards. The proposed metrics include operational expenses, adaptability, inventory expenses, delivery performance, and initiatives designed to aim at cost reduction (Cadden et al., 2020; Zhan & Tan, 2018).

2.6 Research Hypothesis

H1: *Supply chain resilience positively influence supply chain performance*

H2: *There is a positive relationship between supply chain resilience and supply chain viability*

H3: *Supply chain viability mediates the relationship between the supply chain resilience and supply chain performance*

H4: *Supply chain digitalization significantly moderates the relationship between supply chain resilience and supply chain viability.*

2.7 Hypothesis Development

Thorough historical studies have significantly helped us learn about the connection between supply chain resilience and performance (Sturm et al., 2023). Resilience is like shield against disruptive events, and thus, it allows bouncing back after difficult situations and maintains acceptable performance levels (Novak et al., 2021). Therefore, resilience aids businesses to maintain reasonable performance levels (Liu et al., 2018). Supplier flexibility, agility, integration, or reengineering, imposes rather a huge impact on the efficiency of organizational performance and risk control. As a matter of fact, flexible supply chain is capable of delivering high levels of performance and competitive advantage simultaneously (Liu et al., 2018). The reason is that it will help the firm react faster than its competitors to disruptive events which leads to market share and long-term profitability (Parast, 2022). On condition of the ability to redistribute the infrastructure and resources, an organization remains resilient and maintains risk control (Ambulkar et al., 2015).

Take into consideration supply chain resilience. It comprises three various abilities that include absorptive ability, reaction ability and recovery ability (Parast, 2022). The ability to make some preparations in advance is known as the absorptive ability, preparation during a disruption event is termed reaction abilities and recovery ability identified after disruptions events occur. Companies develop such capabilities by combining an impressive array of resources in a way that they can react to diverse delays (Parast, 2022).

Supply chain reliability is in turn directly influenced by the abovementioned itself: absorption capacity and more importantly, improves overall performance (Azadegan et al., 2020). Such volatilities drive up the market share and sustain the levels of costs and make operations profitable (Shekarian et al., 2020). Such a management is referred to as reaction capacity since it involves powerful risk-management actions whenever encountering the conditions in the market place. With better decisions being made, quick reaction implies that the supply chain will work efficiently (Dubey et al., 2020).

The more the organization has outstanding reactive capacity, the higher the chances made by participating in horizontal and vertical joint-venture with suppliers in the supply chain. Partnerships facilitated in these ways allow spreading vulnerability and sharing risk within the network (Ali et al., 2021). This form of collaboration serves to implement protection against external risks as well as improve overall performance of the entire supply chain amidst a disruption event by implementing stronger internal control within the said chain (Shekarian et al., 2020). Increasing the supply chain recovery capacity can contribute immensely to minimizing the losses and enhancing the operations (Ponomarov & Holcomb, 2009). It has been established in the previous studies that there is a positive correlation between supply chain performance (SCP) and supply chain resilience (SCR) (Sturm et al., 2023). The following theory is tested in this study in turn:

H1: Supply chain resilience positively influence supply chain performance

The ability to cope with accidental events and be able to recover following disruption has been defined as resilience. COVID-19 generated a surge of scholarly interest in supply chain resilience-related research (Bier et al., 2020; Chauhan et al., 2020; Dolgui et al., 2020; Lucker et al., 2024; Namdar et al., 2020; Sawik, 2018). The current resilience theories often lack any framework that directly responds to disruptions such as pandemics, wars and prolonged crisis (Ivanov, 2020). The notion of supply chain viability has arisen to fill the gap in research regarding long-term endurance during intense and unforeseen disasters (Ivanov, 2020; Ivanov & Dolgui, 2020b).

Viability can be viewed as a broad concept of resilience, highlighting the ability of organizations and entire industrial sectors to survive. The "bounce-back"

strategy of a closed system view is replaced with an open system framework that highlights "bounce-forward-and-adapt" tactics (Ivanov, 2020; Ivanov & Dolgui, 2020). The concept of viability includes resilience, which means resilience will have positive impact on viability (Wieland, 2021). The meso-level of resilience, as described by (Azadegan & Dooley, 2020), is also in line with viability, which is acknowledged by researchers and practitioners as a crucial concept for managing serious disruptions and guaranteeing long-term survival of supply chain (Hofmann & Langner, 2020; Ruel et al., 2021).

Businesses must establish and maintain reliable, efficient and viable supply chains capable of sustaining operations and fulfilling demand during major disruptions. The timely delivery of essential goods and services to customers during extended crises is dependent upon supply chain viability (Hofmann & Langner, 2020; Ruel et al., 2021). The COVID-19 pandemic has exposed substantial weaknesses in the resilience of numerous supply chains, where complex supply chain networks disintegrated due to disturbances at local nodes, causing a ripple effect that led to weakened connectivity (Ivanov, 2020).

The key component of supply chain viability is resilience (Bier et al., 2020). Supply chain experiences both positive and negative events. Viability evaluates both favorable (profitability, market expansion) and unfavorable (disturbances) events. A system is resilient if it can bounce back from shocks and continue operating (Ivanov, 2020). We refer to a supply chain as viable if it can modify and adapt the supply chain to massive disruption to maintain performance and survive in changing circumstances (Ivanov, 2020). Hence, the study suggests that supply chain viability and resilience have a positive relationship.

H2: *There is a positive relationship between supply chain resilience and supply chain viability.*

Supply chain resilience was essential to enhancing supply chain performance during crisis especially during COVID-19. However, these impacts might be indirect and mediated by concepts like supply chain viability, which might help manage the major supply chain disruptions and uncertainties (Ivanov, 2021). The development of a flexible and adaptable supply chain is crucial for achieving supply chain viability (Ruel et al., 2021). The viable supply chain is dynamically flexible and value adding

network that is resilient, sustainable, and has adoptable capacity. SCV is modifying capacity allocations and utilizations to demands in reaction to internal and external changes to secure the long-term provision of products and services (Ivanov, 2020).

Supply chain viability (SCV) has a significant impact on the relationship between supply chain resilience (SCR) and supply chain performance (SCP). Firms once faced by such occurrences as COVID-19, global wars, political instability, and epidemics require an in-depth knowledge of the supply chain viability (SCV). Supply chain viability (SCV) can be defined as the capability of a supply chain to both sustain itself and endure in a dynamic environment through structural redesign and performance planning (Ivanov & Dolgui, 2020).

The disaster that is long term such as a global pandemic, natural disaster, or economic upheaval- resilience in its traditional understanding can no longer sustain it (Ivanov & Dolgui, 2020).What we need however is a model that not only recovers but which keeps up with evolvement in the uncertain market. The article by (Ivanov, 2020) recently mentions that previous resilience plans see disasters as one off events and concentrate on returning to normal position. This model was once acceptable in cases where shocks were relatively small, but in uncertain world in a scenario where there was long term disruption then it is not enough (Ivanov & Dolgui, 2020). Combining the resilience and supply chain viability needs to become a priority in order to keep the supply chains healthy and competitive (Singh et al., 2019).

When companies actively map and model their supply chains are faster in identifying issues and more willing to address them (Ivanov, 2021). When companies' structure redesigns or performance planning, they effectively manage disruption and ambiguous occurrences more successfully. (Ivanov, 2021) concludes that supply chain resilience and sustainable development should be treated as twin pillars—each depends on the other, and together they support the long-term supply chain performance of any organization.

After observing how organizational uses the resources, it is clear that the SCV and SCR interact to some degree in the presence of disruptions. Viability enables the rapid distribution of resources and enhances collaboration between partners, which improves resilience and performance (Hofmann & Langner, 2020; Ruel et al., 2021). The companies that have attempted to enhance the supply chain must prioritize

viability when it comes to sustainability in a volatile external environment and preserve its competitive advantage and performance. The perception of SCV to mediate in this contact may enable a better understanding of the capability of enhanced viability to implement better resilience strategies that directly affect performance. Accordingly, the following hypothesis is put forward.

H3: *Supply chain viability mediates the relationship between the supply chain resilience and supply chain performance*

The prevailing changes in the market conditions all over the world have made organizations to encounter supply chains disruption. With recent world events, such as the COVID-19 pandemic, ongoing conflict between Russia and Ukraine and the current war between Palestine and Israel, we are encountering more and more difficult and uncontrollable challenges of supply chain influencing factors. Thus, the consideration of digital technologies is quite important assuming management by companies who want to enhance the level of supply chain performance. The digitalization includes artificial intelligence (AI), blockchain technology, the Internet of Things (IoT) and other innovation related to Industry 4.0. The combination of these technologies enables traditional supply chains to be converted into the more flexible and agile supply chains and to stay competitive (Zekhnini et al., 2020).

The COVID-19 epidemic demonstrated the value of the supply chain viability in the contemporary environment. Supply viability does not only relate to recovery efforts to halt disruptions, but in changing towards adjusting to such changes (Ivanov, 2020). Supply chain viability SCV can be defined as the capability of enjoying an evolving environment due to a redesign of the structure and performance planning with long-term implications (Ivanov & Dolgui, 2020). The supply chain becomes more resilient through the provision of the latest data, facilitating forecasting, and automated decision-making via digitalization enable organize and help with the provision of the latest data and forecasting as well as automated decision-making (Ivanov, 2020).

Pattern and trend analysis of large data sets can be handled by artificial intelligence within companies. Technologies in artificial intelligence boost accuracy of the demand and inventory management. This ability allows firms to be more adaptive to shifts in the demand of customers, hence enhancing their resistance to

disruptive processes (Buyukozkan & Gocer, 2018; Zekhnini et al., 2020). Consider it high-tech forms of early warning: when artificial intelligence integrates into the workflow of any company, companies will be able to identify the danger way before it occurs and preemptive measures before any disappointment strikes. Such an initiative will put the chain in a stronger position and make it more reliable over the long-term perspective (Zekhnini et al., 2020). To some extent blockchain technology throws light on what is going or where in the chain and therefore this enables the problems to be known before they blow up. Higher levels of transparency, traceability Block chain technology in its fundamental sense is achieving the ability to respond to the risk that applies when there are the surprise events, in which companies are even more capable of controlling them (Sanka et al., 2021).

It implies that the blockchain system is decentralized and therefore we can monitor the stream of information and goods without the fear of third party bugs and frauds. It is a receptivity that also brings about building trust between partners and, as such, helps to work both with partners and addresses any issues fast (Sanka et al., 2021; Srivastava & Dashora, 2022).

The other powering force behind the model of the circular economy is digitalization. Companies have been given an opportunity to manage their input chain using digital tools ensuring that they not only produce and market products but value can also be collected on waste. The countless supply chain management increases the resilience and sustainability of any supply network, baking new components of revenues and reducing the expenses of waste disposal (Zekhnini et al., 2020).

Technology not only enables us to respond to improbable incidents; technology reduces the lag of time between the process of recognizing an issue and action in regard to the solution (Sanka et al., 2021). Big-data analytics and the Internet of Things (IoT) allow firms to track supply chains in real-time, and, therefore, plans can react to disruptions on the same level in the long term (Buyukozkan & Gocer, 2018; Zekhnini et al., 2020). Digitalization has a colossal impact on the managerial decision making. The more a business engages in the process of digitalization, the higher its ability to cushion against the unexpected turbulence thus ensuring that its operations continue in the long run with achieve financial stability (Sanka et al., 2021).

Amid increasing complexities of international trail of occurrences, companies seek combined approaches incorporating resilience and viability concepts of the supply chain management. Those companies that manage their digital practices with resilience will have higher chances to attain long-term competitive advantage in the progressively unpredictable market (Ivanov, 2021; Zekhnini et al., 2020).

The relationship between the supply chain resilience and the supply viability is also related to digitization. The implementation of innovation in the form of artificial intelligence and blockchain will allow organizations to increase their ability to adapt to change and ensure their survival in the long term (Ivanov, 2021). To be ready to the constantly evolving situation on the market it is crucially important that businesses keep on developing their digital transformation. The future studies should include how various digital technologies are possible to integrate as well as include the potentially possible adoption to enhance both SCR and SCV (Zhou et al., 2023). The new studies support the validity of this theory that indicates increased digital capabilities add to the supply chain resilience (SCR) and improve supply chain viability (SCV) (Liu et al., 2023; Khadija et al., 2023). It is also revealed that through the successful implementation of digital technology, supply chain partners become more collaborative when facing disturbances, which intersect with this that digitalization moderate this interaction (Brusset et al., 2023).

The combination of digital technologies, such as block chain, artificial intelligence, and the Internet of Things, all these aspects influence policies, supply chain activities, and customer satisfaction to a large extent (Zhou et al., 2023). The more easily companies integrate their information systems and data; the more able they are to view their supply-chain network and react more promptly and positively to disruptive events and suggests uncertainties (Zhou et al., 2023). As it is stated in (Yu et al., 2023), digital tools were essential to maintain supply chains functioning at an expected level throughout the crisis. This led to the firms adapting promptly and constantly to the disruptions in the global supply chain (Ivanov & Dolgui, 2020). According to this literature, the scholars hold the view that digitalization affects both the supply chain resilience as well as the supply chain viability to a considerable extent.

H4: *Supply chain digitalization significantly moderates the relationship between supply chain resilience and supply chain viability.*

2.8 Framework

The conceptual framework has been formulated based on the literature review and the hypothesis proposed to support the relationship between study variables. The framework shows the direct impact of supply chain resilience on supply chain performance, and the mediating role of supply chain viability, and moderating role played by digitalization.

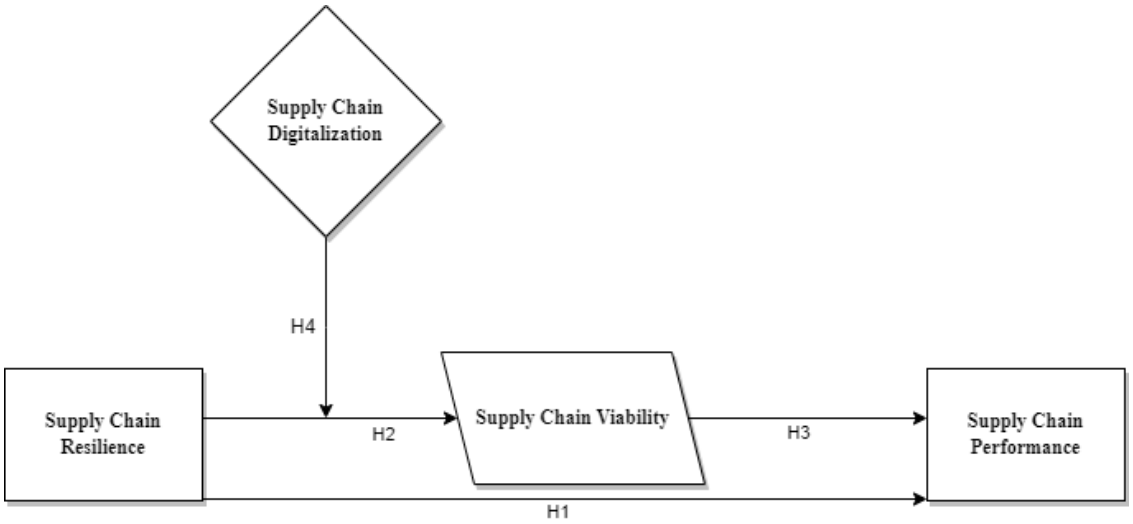

Figure 2.1 Conceptual Framework of the Study

There are different aspects of operations, which affect the supply chain performance of a company. Greater supply chain performance requires the proper management of these factors. These include productivity, satisfactory customers and profitability of supply chain. It is a necessary and crucial sign of the performance of a company since it shows the general health and efficiency of the supply chain. The independent variable in this framework as shown in Figure 2.1 is supply chain resilience, supply chain digitalization as a moderating variable; supply chain viability is playing a significant role of mediating variable and supply chain performance act as dependent variable. The study can provide businesses with knowledge to remain competitive by investigating the relationship between these variables in this framework.

Viability is more general concept because viability is the power to grow and to survive. Supply chain viability dimensions are resilience, sustainability and adoptability. Additionally, digitalization reshapes the contemporary supply chains, as it already offers technologies and tools, which can far greater benefit the contribution to resilience. Supply chain viability (SCV) is used as mediator since it is the long-term ability of a supply chain to maintain operations, respond to disruption, and remain operational. Although resilience implies the short-term shock absorption and recovery, and digitalization improves coordination and responsiveness, the effects of these factors on performance are achieved via SCV. Through the combination of these capabilities, Supply chain viability is a mediator that demonstrates the way resilience and digitalization can collaborate to ensure high and sustainable performance of the supply chain. This methodology is especially relevant in unpredictable and dynamically changing conditions which are frequent in developing countries like Pakistan.

Live monitoring and analytics prediction and transparent startup decisions introduce another scale of opportunities which offered by AI, internet of things, blockchains and a range of other technologies. This framework investigates how technologies integration, enhances sustainability and efficiency of the supply chains. Elements of the digitalization of a supply chain are blockchain technology, the internet of things (IoT) and artificial intelligence (AI). Supply chains viability capabilities can be grouped into capabilities of resilience, sustainability and adaptable capabilities. Lastly are the dimensions of the supply chain performance operational performances.

There are an ever-growing number of businesses acknowledging the need to implement digital solutions as their supply chain strategy. Much attention should be given to understand the interaction of these technologies and the variables that can impact on the performance of the supply chain and its viability. Their interaction can create a strong framework (figure 2.1) that can assist a firm to overcome the disturbance the supply chains are facing in this unpredictable environment. (Kouhizadeh et al., 2021; Ivanov, 2021).

Digitalization is not a mediator in the sense it is not the mediating mechanism by which supply chain resilience (SCR) influences performance. Digitalization as a

moderator can minimize or maximize the effect between variables. Digital technologies can contribute to stronger coordination, decisions in real-time, and responsiveness providing an additional or lesser effect of resilience. Therefore, digitalization is a facilitating capability, which technically is suitable as a moderating variable (Ivanov and Dolgui, 2020).

CHAPTER 3

METHODOLOGY

3.1 Research Approaches

The present study investigates the topic of supply chain performance through deductive research approach. The hypothesis involved the fact that the supply chain resilience, the supply chain viability, and digitalization have a strong impact on performance outcomes. The accepted theories and conceptual models are the fundamental aspects of study model. We adopt a scientific framework, which puts into consideration a statistical examination and data gathering.

The study is initiated through theoretical concepts and the effort toward the evidence based validation. The method then adopted in this paper is a logical top-down approach.. This study was a logical and fairly reasonable research conducted on the proposed variables amid SCR, SCV, and digitalization. This approach ensures that it not only guarantees the validity of the results obtained but also applies it on a broad scope of situations on the basis of data. The variables, the scales of measurement, and methods used in the analysis ensure that the study design will be based on high level of scientific accuracy in testing the hypotheses suggested. The study is based on logical research of a questionnaire design which compares and ensures comparability and reliability of the responses. The design of the survey has led to the validity of the gathered information as it minimizes the degree of bias and ambiguity in data gathered. Although it implies a full-fledged and the rightful analysis of statistics, the potential of biased answers in the response can be minimal. The process aids the researchers to pursue successfully, the direct and indirect relationship between SCR, SCV and digitalization and the entire effects of these two variables on the operation of the supply chain.

This research highlights the focus on practical and real world knowledge as well as more on theory, where the knowledge and experience of the supply chain

managers working in the manufacturing segment of the electronics and electrical manufacturing firms has been acquired. The knowledge of these professionals can assist this research to explore the role of resilience, viability and digitalization in either positively or negatively influencing the performance of supply chain. Such an approach is not only a guarantee of a stand concerning the validity of the theory, but, simultaneously, rather helpful results of the world of business and industry.

This will be carried along with the already constituted literature, on the supply chain management. The results will help in knowledge to contribute businesses to meet consumer demand and environmental volatility with the available supply chain resources. The study being used is a deductive research methodology in which conclusion drawn would be beneficial since it would be supported by the existing values. Policy makers and business managers as well as academia will find the study helpful. This assists such individuals to come up with mechanisms that would result to supply chain health, establish resilience and viable supply chain in coming up with improved supply chains.

Finally, the paper aims to fill the gap between the theory and practice by offering evidence-based recommendations that can be adopted in inform strategic decision made within supply chain management. This logical and temporal arrangement of the deductive methodology ensures contribution of the research high significance. It offers recommendation of future research and practical tips to companies that trying to enhance their supply chain activity in a more digital and unpredictable environment.

3.2 Research Strategies

The study is using written questionnaires in English as the research design, which is standardized to intentionally and wisely collect the data on an appropriately selected questionnaire from managers of electrical and electronics manufacturing industry in Pakistan. A successful solution to data collection of large volumes of data is through a structured survey strategy. Consequently, this will help in conducting the study to explore more specifically the countless effects that enhance the supply chain performance (SCP). Completely structured surveys will ensure the uniformity of the results and enhance the predictability and dependability of results retrieved. In addition, a quantitative method will be adopted such that the results of the analysis

that practically act against the significant variables will render it more valid and helps in other future research studies.

The strategy provides the integrated picture approach to the gather ideas of the managers having the practical experience of the supply chain management skills. Their perceptions can contribute to deeper characterizing the roles SCR, supply chain viability and digitalization are currently playing in supply chain performance. Furthermore, the relationship between the most important variables, i.e., resilience, viability, and digitalization, is carefully examined using statistical approach and a quantitative method. This quantitative approach helps the scholar to objectively measure, analyze and examine data and allowing the measurement of simple concepts could be quantified through statistical instruments such as mediation /moderation analysis, correlation analysis and regression analysis. The resilience was investigated on supply chain performance both direct and indirect sense.

These survey based research methods are able to provide results, which could be used upon a larger population within the electronic and electrical manufacturing industries. The results of this research can be used since the survey has been administered to various managers representing several companies. The data is collected based on the online Google forms questionnaire from managers of the electrical and electronics manufacturing industry. The future researches can follow the same methodologies to authenticating the results or broaden the scope of the generalization provided which enhance design validity. This undertaking will play a big role in enhancing the body of knowledge in the supply chain management. This gives supply chain managers, legislators and scholars, the opportunity to have viable implications drawn on the basis of empirical studies on the interaction of supply chain resilience, viability and digitalization and on the outcome performance results.

Furthermore, the aspect of the analysis of the systematic and the ordered survey technique can ensure that not only the results of the study but also the practices are being put into action in positive ways. The results of this study would assist the managers to make wise decision to improve SCP in the areas of the electric and electronics manufacturing industries. It provides the investigation of the most important variables that contribute to the supply chain performance. The contemporary world has also become unpredictable due to alterations of the climatic

environment, inconsistent natural disasters, epidemics, war between counties, political instability, technical progress and altered customer needs.

3.3 Research Choices

Quantitative Research Methodology: The work examines the variables relationship in with concentration to gather quantitative data and to justify them by the help of statistical instruments. This approach is aligned with the deductive approach, as it facilitate the pre-established theories.

The quantitative framework provides the researcher with the prospect of employing the large number of the statistical data, which ensures that the analyses are promising and structured. The aim is to conduct heavy research as regards to the interrelation between variables. The accuracy and reliability of the results in the study have been established by the quantitative data. This shall reduce subjectivity and biasness in the analysis of data. Such findings will be useful to legislators, professionals as well as scholars.

3.4 Time Horizon

This study follows the cross sectional research design; hence, it was collected at a specific time and not within a long duration. The method is important because it will give the information about the recent tendencies and practices and experience of the electrical and electronics manufacturing firms. This objective achieved by the help of collecting data using questionnaires from managers at single point in time. It is quite a flexible design that is employed in a wide number of fields. This will be a timesaving and economical method of analyzing critical issues impacting the supply chain as all the data are collected at one point in time. It would particularly be useful to industry practitioners, legislators and those researchers who need timely and relevant data that will help them decision making processes.

Nevertheless, the disadvantages of the cross-sectional approach are quite numerous, among which the fact that suggestive method does not provide the observation of trends over time. It is doing well in assessing the current condition of the supply chain dynamics but does not provide any information about the progression of the linkages of variables due to changes in the market, and technological

developments. The results are also used to describe the association between supply chain resilience (SCR), digitalization supply chain viability (SCV) and supply chain performance (SCP) in the current state; however, they probably are not reflective of long-term trends and potential changes in the relationships.

Using the methodology, which is rooted in longitudinal studies, in the future would contribute to the enhancement of this evidence and closing this gap. The researchers collaborating on a longitudinal study would also track the transformation of SCR, SCV, digitalization and SCP in coming years. This will assist them to inquire on the reaction and connection of these variables to external factors. Such a methodology would allow gaining a better understanding in the long-term effect of digitalization, SCV and SCR on supply chain performance. This will empower the supply chain managers and the lawmakers to be in a position to formulate more flexible and sustainable initiatives to improve the supply chain performance in order to stay competitive in this unstable environment. To examine constantly evolving trends and long-term effect, it is therefore recommended that future research put that aspect into consideration by incorporating the longitudinal approach. That will ensure a comprehensive and advanced insight into how these variables will facilitate the continuity of the businesses in unpredictable and changing environment.

3.5 Data Collection and Analysis

The information was gathered by using distribution of organized questionnaire. The questionnaire distributed and information gathered using research survey tool through an online Google form. The questionnaire will assist the researcher to collect the information obtained in this research. This aesthetically designed questionnaire addresses all spheres of supply chain resilience, digitalization, viability, and performance. The questionnaire was issued to each one manager of the 47 Pakistani electrical and electronics manufacturing companies. Such managers are directly involved in the operations of the supply chain. The respondents who are the most competent and capable of offering accurate and insightful data concerning the effects of digitalization, viability, and resilience to the supply chain performance are the managers.

The non-probability purposive sampling approach was used to select the participants. This is particularly applicable in conducting a research on a field of study that involves an expertise because it ensures that responses is made by individuals with a wide understanding of operations of a supply chain. The objective of the study was to collect the quality information of industry-related expertise and actual field experiences. The samples of study were target employees who were supply chain managers and field experts. Purposive sample is also useful in enabling the sampling of individuals having personal experience with digital transformation initiatives, resilience-building measures and issues of viability within their respective companies.

The questionnaire that includes the study questions was consisting of closed-ended questions in order to obtain quantitative data. The closed-ended questions that are formulated using 5 points Likert scales are to be made consistent and simplify the analytical process.

Also, ethical considerations were prepared with seriousness to ensure that all the participants provided their informed consent to respond to the survey questionnaire. The identification and secrecy of the respondent is a commitment towards giving sincere and impartial responses.

3.6 Analysis of the Information

Upon the conclusion of the data collecting process, we conducted a quantitative analysis with the help of the statistical tool SPSS. This is to ensure that the interaction of the important variables has been identified and studied accurately. The interactions between the concepts of supply chain resilience, digitalization, viability and performance of the supply chain were examined by statistical methods.

We interpreted the direct relationship between digitalization and supply chain resilience on the overall supply chain performance with regression analysis. The regression analysis assists in explaining the impact that these factors exert on the performance of the supply chain. The research objectives include confirmation of whether the resilience and digitalization are having a statistical significance on the performance of the supply chain operations.

Mediation studies and the analysis of moderation assists us to identify the relationships between the variables. We examine by mediation analysis, whether supply chain viability is a mediator between supply chain resilience and supply chain performance. The approach facilitate us in discovering whether resilience influence performance having viability as mediator. Nonetheless, moderation analysis is also useful in determining the relationship of moderator (digitalization) of the connection between resilience and viability to supply chain performance. The findings of these studies contribute to the deeper comprehension of relations between various variables under the supply chain.

We have applied correlation analysis so that to appraise relationship and also the effect of the significant variables. It examines the positive or negative relationship between resilience and digitalization, the supply chain viability and performance. The effect of these aspects is shown by the correlation analysis. High values of the correlation signify a significant association, whereas small value of the correlation signifies a narrow or no relations amongst different variables. We evaluate sets of different data and determine the statistical significance. Such statistical tests include the chi-square analysis, t-test, and the analysis of variance (ANOVA).

These detailed statistical methods provide the businesses with a detailed perspective on the impact of resilience, viability and digitalization on the performance of supply chain. The information gained during the data analysis would be very helpful to business managers. These suggestions will help them in improving the competitive quality and effectiveness of the entire supply chain.

3.7 Ethical Considerations

Observing ethical standards helps in preserving the confidentiality of the data regarding the participant and as a result keeps the rights safe. The participants in this research were guaranteed that they have their right to make choice. Every person is informed in detail about the aims of study, procedures and degree of involvement anticipated to participant. The practice guarantees the upholding of the morals of the research. All the participants are given an elaborate guideline covering the aim of the research before participation. Furthermore, they can participate in this study, or they can freely withdraw the study without any difficulties. This will assure that we respect

the right of the participant in making his/her own decisions and conducting ethical research.

The guidelines set on data security will preserve confidentiality and privacy of the participants in the research. We make sure that we safeguard all personal information. The information collected shall be kept in a safe place to avoid breach of information. The using of information is limited to study purpose. We did not publish it to third parties and avoid any commercial benefits of it. The ethical view adopted in the research study strongly depends on informed consent. This process will also make the participants aware of the objectives of the research, the kind of data that will be collected, the confidentiality policies that will be used, as well as their right concerning participation. The research project makes sure that the people undertake it voluntarily.

3.8 Unit of Analysis

The proposed study relies on the quantitative approach to research and employs a cross-sectional research design to collect data on Pakistani electrical electronics manufacturing sector. This study aims to bring together the views of the industry experts in an effort to develop an analysis of how resilience, viability and digitalization influence the performance of the supply chain.

In this research, the electrical and electronics manufacturing companies were identified based on the purposive sampling method, and companies that have developed the supply chain processes, use digital technologies actively, and are large enough to give reliable and significant information were chosen. The identification of firms was made based on major industrial clusters and business directories to make the firms accessible and relevant to the research aims. The reason behind this selection is that this sector works in a complex and technology-driven environment, with supply chain interruptions a usual occurrence and digital tools a crucial factor, which makes it a perfect environment to examine the relationship between resilience and digitalization in supply chain performance in practice.

For the purpose of this investigation, the population size is comprised of 53 companies, while the sample size is comprised of 47 companies that manufacture electrical and electronic goods. The participants consisted of managers from the

companies, as they possess the critical information and experience necessary to provide valuable insights into supply chain processes.

Even though 196 sample size were initially calculated, but the sample size was narrowed to 47 by determining the organization as the unit of analysis, as per the feedback obtained during the synopsis defense. In this regard, only one informed response collected from one manager of each electrical and electronics manufacturing firms. This strategy also guaranteed that the data reflected organizational views. Thus, the sample size reduced to 47, as there is limited number of electrical and electronics manufacturing firms in Pakistan.

The selection of participants was carried out using a non-probability purposive sampling technique. Only those individuals who have direct knowledge and skill in supply chain management within the industry are included in the study. The research is to provide findings that are both practical and usable, with the goal of contributing to both academic research and industry practices in supply chain management. The gathered information will aid firms in enhancing their operational efficiency and effectively addressing market challenges.

3.9 Measurements (Questionnaire)

Supply chain resilience and supply chain performance will be measured using the scale adapted from (Zhao et al., 2023) which includes five items.

Supply chain viability and supply chain digitalization will be measured using the scale adapted from previous research (Yu et al., 2023) which includes five items.

This questionnaire will use a Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree)

The scale was adapted from previous studies. The scale was modified to make them appropriate for Pakistan supply chain context. The pilot study was conducted and the reliability tested using Cronbach’s alpha to make sure the validity and consistency of scale items.

CHAPTER 4

DATA ANALYSIS AND DISCUSSION

4.1 Demographic Data

The descriptive statistical study of the participants indicates that 47 managers from each company participated in the survey questionnaire. The largest age group comprises individuals aged 25 to 35, representing 44.7% of the total sample size. This group comes in second, with 34% of the respondents being between the ages of 36 and 40. In the entire sample, the age groups between 41 and 45 years and between 51 and 55 years each make up 8.5% of the total. With a cumulative percentage showing that 82.2% of the respondents were between the ages of 30 and 40, thus, this survey is characterized by a significant representation of younger professionals. Regarding the educational background of the participants, the majority possess post-graduate degrees, which are the most frequently represented qualifications within the sample. The remaining participants have completed their Masters.

The electrical electronics-manufacturing sector includes a wide range of managerial and specialized roles. The designation of Manager constitutes 49.1% of the entire dataset, making it the most frequently utilized category. There is a higher managerial position or job position- Zonal Manager, Accounts Manager, Head of Sales, Business Development manager, Logistics Manager, DGM Supply Chain, and logistics Management which comprises 8.5% of the sample. The positions are less frequent and the Manager Sales position, Supply Manager Position and the BM contain 6.4, 6.4 and 6.4% respectively of the entire sample.

The participants of the research study are managers working on 47 separate electrical electronics organizations in Pakistan. Other major companies which are presently engaged in operation in Pakistan are Hisense Pakistan, Waves Corporation, Digital World Pakistan Pvt LTD (Gree/Ecostar), Pakistan Cables Limited and Pak Elektron Limited, Dawlance, Master Group, Siemens, Boss Home Appliances and 38

others. This superb portrayal will assure a complete and acceptable dataset of the sector.

4.2 Reliability results (Cronbach's Alpha)

In order to measure internal consistency of the survey items, we conducted the reliability analysis using Cronbach's alpha. So as the results here all of the alpha values are above 0.7 showing good reliability. Hence, all of the scales is acceptable for further statistical analysis.

Table 4.1 Reliability results (Cronbach's Alpha)

Construct / Variable	Number of Items	Cronbach's α
Supply Chain Resilience (SCR)	5	.717
Supply Chain Digitalization (SCD)	5	.762
Supply Chain Viability (SCV)	5	.736
Supply Chain Performance (SCP)	5	.709

Note. N = 47. Cronbach's Alpha values above 0.70 are considered acceptable.

In order to measure internal consistency of the survay items we conducted the reliability analysis using Cronbach's alpha. As the results shown in Table 4.1 is that all of the alpha values is above 0.7 showing good reliability. Hence all of the scales is acceptable for further statistical analysis

4.3 Correlation Analysis

The Correlation Analysis is the discussion of the correlation between variables. Supply chain Resilience (SCR), Digitalization (D), Supply chain viability (SCV) and Supply chain performance (SCP).

Table 4.2 Correlation Analysis

Variables	Digitalization	Supply chain Viability	Supply Chain Performance
Supply Chain Resilience	0.331*	0.128	0.712**
Digitalization		0.642**	0.521**
Supply Chain Viability			0.643**

Note. N = 47.
$p < .05$*, $p < .01$**, $p < .001$***

Table 4.2 presents correlation with a rather positive and promising outcome between Supply Chain Resilience (SCR) and Supply Chain Performance (SCP) (r = 0.712, p < 0.01). This is an indicator that better performance is significantly aligned with better level of resilience in supply chains. This is in support of the theory that strong supply chains resilience is better positioned to withstand disruptions and continuing its integrity of performance.

Digitalization (r = 0.331, p = 0.05) and SCR have revealed that there is a moderately positive correlation. This implies that it has less effect on the resilience of supply chain (SCR) compared to that of digitalization on the viability and supply chain performance (SCP). Yet, digitalization helps to make supply chains stronger. The correlation between SCR and Supply Chain Viability (SCV) has very poor values and not statistically significant (r = 0.128, p = 0.395). It is stated that resilience does not have a serious impact on viability using statistics.

The performance of the supply chains (SCP) (r = 0.521, p = 0.01) and supply chain viability (SCV) (r = 0.642, p = 0.01) are simply already highly correlated with digitalization. This suggests that, to a notable extent, digital transformation greatly raises the viability and supply chain performance. This underlines the need of using digital tools and technology in enhancing supply chain performance's adaptability as well as effectiveness. Supply chain performance (SCP) and supply chain viability (SCV) show a significant correlation (r = 0.643, p = 0.01) highlighting the need of

viable supply chains. Ultimately, the observed weak positive correlation between SCV and SCR suggests that resilience does not have a direct impact on viability.

The findings of this investigation indicate the essential role of digitalization in improving supply chain viability and supply chain performance. Digital transformation is to be placed on the first agenda among those companies that strive to enhance their approach to supply chains in case they intend to increase their overall responsiveness and performance.

4.4 Regression Analysis

The final results of the linear regression model suggest that Supply Chain Resilience (SCR) is a significant variable in predicting Supply Chain Performance (SCP), overall, 56% of the variances in Supply Chain Performance (SCP) are explained within a p-value of less than 0.05. An increase in SCR results in a quite significant improvement in SCP, suggesting a strong positive correlation between the two factors. This large share of variance indicates the relationship.

Table 4.3 Regression Analysis

Variables	B	Std. Error	Beta	t value	p value	LLCI – ULCI
SCR → SCP	0.642	0.095	0.712	6.719	0.000	0.449 – 0.834

Note. N = 47. SCR = Supply Chain Resilience, SCP = Supply Chain Performance, B = unstandardized coefficient, Beta = Standardized coefficient, t = t-value, p = p-value, LLCI = Lower level confidence interval, ULCI = Upper level confidence interval.
$p < .05$*, $p < .01$**, $p < .001$***

With the beta value of 0.712, providing evidences of the significant role of resilience on the performance of the operations of the supply chain in Table 4.3. The results are validated by an F-statistic ($F(1, 44) = 45.139$, $p < 0.001$), which indicates that SCR has a significant tendency on SCP, and this improves the statistical significance of the model. Moreover, to maintain the credibility and validity of the findings, there is the SCR confidence interval with the range between 0.449 and 0.834.

These results suggest the importance that the resilience effect has in augmenting the performance of the supply chain management. The more businesses put in place resilience in the form of risk mitigation to an extent of employing proactive risk management, building flexibility in their processes and an overall strategic plan, the greater the probability is that they will be in a position to achieve a higher efficiency, its flexibility, as well as an overall performance of its supply chains.

4.5 Multicollinearity Diagnostics (VIF Values)

Here is the table, which present variance inflation factor (VIF).

Table 4.4 Variance Inflation Factor (VIF)

Variable	VIF	Acceptable Threshold
SCR	1.138	< 5
SCV	1.903	< 5
Digitalization	1.723	< 5

Note. SCR = Supply Chain Resilience, SCV = Supply Chain Viability, VIF = Variance Inflation Factor.
VIF < indicate no multicollinearity

As shown in Table 4.4, all values of VIF are less than 5 which proves that multicollinearity is not a problem and regression estimates are stable.

4.6 Normality Diagnostics (Skewness & Kurtosis)

In order to examine the distribution of each variable the normality diagnostics was conducted using skewness and kurtosis values.

Table 4.5 Normality Diagnostics (Skewness & Kurtosis)

Variable	Min	Max	Mean (M)	SD	Skewness	Kurtosis
SCR	3.00	4.80	4.00	0.53	–0.19	–0.86
Digitalization	3.00	4.80	4.23	0.47	–1.39	1.74
SCV	2.80	4.20	3.70	0.40	–0.56	–0.46
SCP	3.20	4.80	4.06	0.47	–0.39	–0.39

Note. N = 47. SCR = Supply Chain Resilience, SCV = Supply Chain Viability, SCP = Supply Chain Performance, SD = Standard deviation. Skewness and Kurtosis values between -1 and +1 indicate acceptable normality of data.

The descriptive statistics of all the study variables are shown in Table 4.5. The average score was 3.70 to 4.23 (SCV and Digitalization respectively), which is a moderately high score on the constructs. The standard deviations (SD = 0.40) indicate that the variability in the responses of the participants is rather low.

The skewness was in the range of -0.19 to -1.39 with digitalization having the highest negative skew suggesting that there was a slight manner of concentration at the higher side of the scale. The values of kurtosis were -0.86 to 1.74, most variables had a fairly flat (platykurtic) distribution, the only exception being that digitalization had a moderately peaked (leptokurtic) distribution.

In general, the skewness and kurtosis values were not outside the acceptable range of negative and positive skew, which consists of a range of two. The data are not skewed and kurtoses with a slightly higher value, which does not contravene the assumption of normality and which confirms that the data can be used in parametric tests (correlation and regression).

4.7 Mediation Analysis

Supply Chain Resilience (SCR) and Supply Chain Performance (SCP) represent a very powerful and significant contributor using Macro Hayes Process Model 4 with a coefficient of B =0.5766 and a p = 0.001. This study contributes to the

facts that there is such positive correlation between resilience and performance that the correlation is very strong. It suggests that those supply chains that having high resilience would have a better likelihood to attain the high-performance outcome. Supplies chain viability (SCV) does not play much role in decision of this connection; thus, the mediation effect is not statistically significant. On (-0.0911 0.1890) the bootstrapped confidence interval of the indirect effect covers zero and thus the bootstrapped interval is not identifiable as having little effect by the resilience and performance to viability in the relation. Viability of a supply chain does not play a significant part unlike resilience that has a direct positive correlation with the supply chain performance. On the other hand, viability does not play a major role as mediator. This means that the variables could be very important, including agility, digitalization or innovation that can improve the resilience-performance relationship. Organizations that feel they can improve performance in their supply chain may highlight resilience-building approaches independently with the potential to lead to improvement in supply chain performance as opposed to using viability to mediate improvements.

Table 4.6 Mediation Analysis

Effect	Effects (B)	Std. Error	t value	p value	LLCI – ULCI
Direct Effect SCR→ SCP	0.5766	0.0595	9.6896	0.000	0.4566 – 0.6966
Indirect Effect SCR→ SCV →SCP	0.0649	0.0705	0.92	0.36	-0.0911 - 0.1890

Note. N = 47, SCR = Supply Chain Resilience; SCV = Supply Chain Viability; SCP = Supply Chain Performance; t = t-value; p = p-value; LLCI = Lower level confidence interval; ULCI = Upper level confidence interval. $p < .05$*, $p < .01$**, $p < .001$***

The Table 4.6 explaining viability is not significant (R2 = 0.0165, p = 0.3954) when Supply Chain Viability (SCV) is regarded as a mediator. The weak correlation between resilience and viability suggests that viability has minimal influence on the causal relationship between performance and resilience. Resilience directly increases performance; thus, viability does not statistically significantly mediate or contribute to

this relationship. This observation is another indication that resilience is a performance boosting factor. Nevertheless, there can be other internal or external factors that are not considerate in this model and might impact viability. Such findings indicate resilience as the primary driver of the SCM performance; however, there may be other factors that influence viability. The companies that would wish to enhance their economic outcome ought to ponder the creation of their resilience through the introduction of risk control, adaptability, and computerization instead of using viability as an intermediate variable.

The general model is very strong with a R2 = 0.8157 and p =0.001 the model that explained Supply Chain Performance (SCP) is there with extremely high statistical significance. This fact implies that the Supply Chain Resilience and Supply Chain Viability together serve as significant portion of the performance of supply chain. The rich and significant synergistic impact of these two variables on supply chain performance (SCP) highlights the significance of resilience and viability.

4.8 Moderation

The research on moderation employs the Macro Hayes Process Model 4 to examined influence of whether digitalization has any impact on the relationship between resilience and viability of supply chains. The results reveal that the mediating ability of digitalization has a strong impact. The performed analysis shows that the value of the coefficient = 0.2956 and p = 0.0247 implies the digitalization positively influence the resilience of the supply chain. Interdependence between the resilience of supply chain and the degree of the digitalization level also increases in a statistically significant manner. It is also positive correlation. The existence of this connection can then assist such organizations to be more generously adaptive and functioning experiences to maintain better supply chain performance in changing environment.

Table 4.7 Moderation Analysis

Effect	Coefficient B	Std. Error	t value	p value	LLCI – ULCI	Significant
SCR SCV	-0.0716	0.0935	0.7653	0.4483	-0.2602 to 0.1170	Not Significant
SCR SCD	0.2956	0.1271	2.3251	0.0247	0.0394 to 0.5518	Significant
SCR SCD SCV	0.1691	0.1034	-	-	-0.0752 to 0.3369	Not Significant

Note. N = 47. SCR = Supply chain resilience; SCV = Supply chain viability; SCP = Supply chain performance; SE = Standard error; Beta = Regression coefficient; t = t-value; p = p-value; LLCI = Lower level confidence interval; ULCI = Upper level confidence interval. $p < .05$*, $p < .01$**, $p < .001$***

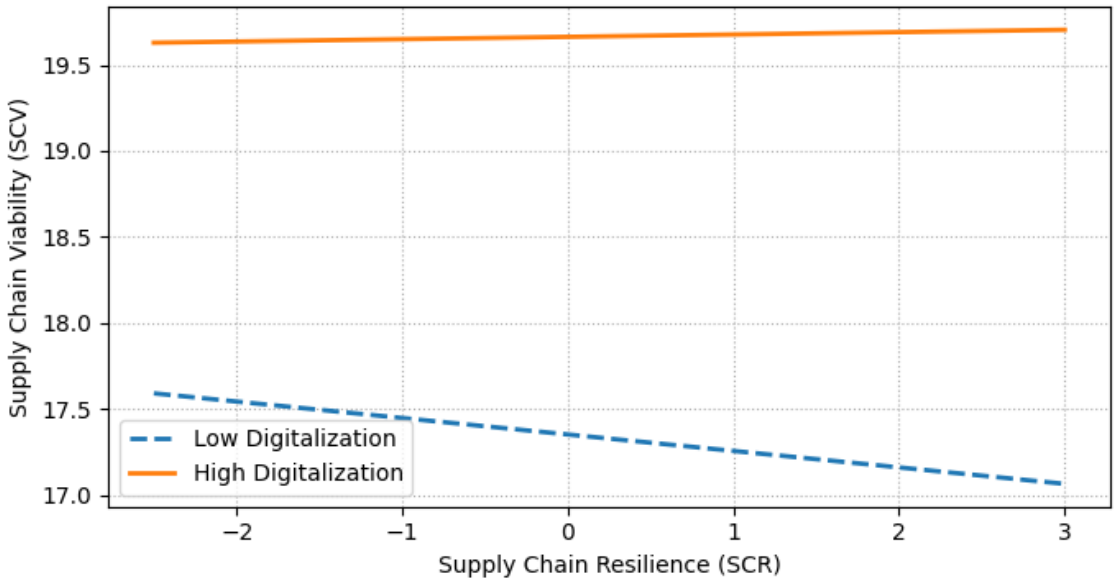

Figure 4.1 Interaction Effect of Digitalization on the Relationship Between Supply Chain Resilience and Supply Chain Viability

According to moderation interaction plot Figure 4.1, the upper blue line shows high digitalization and the lower yellow line is low digitalization, that shows the

higher level of digitalization will significantly improve supply chain viability and performance, without digitalization the impact of resilience on the supply chain viability will be zero, Thus that shows the digitalization is really important.

Moreover, digitalization of operations within the supply chain represented by the coefficient of 0.5719 in Table 4.7 has major impact in determining the viability of the operations in the supply chain as the p-value is greater than 0.001. Thus digitalization is having significant influence on supply chain performance. The outcome shows that the digital transformation is prominent in improving the sustainability of supply chain network. Using digital technology, including artificial intelligence, blockchain, cloud computing and data analytics through which the firms operationalize the digital technology can make the firms absorb disruptions that might come along its way better by steering its operations despite the challenges within the firm. Enhanced visibility, streamlined logistics and inventory management is made possible with digitalization. Digitalization would enable business to streamline real-time tracking, simplify logistics and inventory management. A combination of such elements results in supply chains that are viable, sustainable in long-term.

The coefficient of -0.0716 and the p-value of 0.4483 show that it is not clear if supply chain resilience directly affects supply chain viability, which is significant. One can support this assertion using the p-value of 0.4483. This conclusion suggests that the robustness of the supply chain does not directly influence the viability of the company. Conversely, it appears that viability depends on other factors, such as digitalization, which acts as a facilitator, enhancing the link between resilience and viability. These findings challenge the conventional belief that resilience alone ensures the viability of supply chains. Instead, it underscores the importance of digital transformation as a supplementary factor that enhances the impact of resilience on supply chain viability.

With a coefficient of 0.1691 and a bootstrapped 95% confidence range covering from -0.0252 to 0.3369, the indirect influence of supply chain resilience on supply chain viability through digitalization as a moderator is found to be considerable. This result suggests the significance of this effect. This supplementary data serves as another proof that digitalization somewhat reduces the correlation between supply chain resilience and viability. The relevance of this indirect effect

reveals that, although resilience is a major factor in the success of supply chain operations, the whole influence that it has on viability can only be realized when digitalization is included in the procedures engaged in supply chain operations. This conclusion emphasizes the need for companies to use integrated strategies combining digital projects with resilience measures to reach supply chain operations that are both competitive and sustainable.

According to the findings of this study, the level of digitalization is one of the most important variables. Increased level of digital adoption will enhance both resilience an viability, conversely lower level of digitalization will also affect the supply chain performance. Digital tools that can help businesses better understand the benefits of resilience may include how to become more capable of predicting, preparing and responding to a scenario or disruption within a supply chain. Companies may develop preemptive preparation that will enable them to identify risky situations and avert severe outbursts. To develop such approaches, the assistance of machine learning, automation, robotics, predictive analytics, etc. can be used within supply chain operations.

It is a matter of concern that the resilience facilitates businesses on how to enhance sustainability of their supply chain. The effects of digitalization initiative are the need that it enhances resilience and viability to ensure the basic realization of the supply chain performance. These investments in digital platforms and tools will highly beneficial to a business since it will elevate daily productivity considerably, avert risks and increase flexibility to changes that could occur in the external environment. The companies are able to come up with more flexible supply chain networks because of its digitalization. This will ensure that competitive edge is maintained in the prevailing dynamic business environment.

Thus, firms invest in digital technologies such as AI, IoT, and blockchain will have higher supply chain viability and improved supply chain performance. This support (Buyukozkan & Gocer, 2018), showing that digitalization significantly improve visibility, agility and long term sustainability of the supply chain. Digitalization tools such as Ai, Internet of things, block chain and big data analytics enable firms to adopt structural changes according to the disruptions thereby strengthening supply chain viability and performance.

Besides this, the paper revealed that there is a need to ensure that politicians and corporate leaders encourage the use of digitalization throughout the supply chain. By providing financial incentives, subsidies, and regulatory provisions directed at the companies that invest in the digital technologies may become significant in terms of supporting the process of digital transformation by government agencies, trade groups, and industry associations. Training of employees and being digital literate is the key to the summing of all the advantages of digitalization in the sphere of supply chain management. The sensible use of the benefits of the digitalization process is preconditioned by the presence of robust digital resources.

Moreover, the study emphasizes the necessity to keep on increasing the technological features and delivering new concepts in the supply chain management practices. Businesses that will remain loyal to the exploration and adaptation to new digital opportunities will be in better positions to deal with the complexity of the supply chain operation and sustain the long-term growth. The new technologies, which have exceptional possibilities of increasing the resilience and viability of supply chain, are blockchain, the Internet of Things (IoT) and artificial intelligence (AI). Firms that actively integrate such technologies can be at a superior position of transparency, efficiency and responsiveness regarding the operating practices that constitute their supply chain.

Using the results of this moderation research, it can be shown on the foundation of the correlation between supply chain resilience and supply chain viability that the moderator effect of the digitalization can be meaningful. The results suggest that the existence of the concept of digitalization implied a higher contribution to the supply chain resilience on establishing supply chain viability. The argument highlights the need of the company to relate efforts to enhance resilience with the actions of digital transformation in an attempt to make supply chains more sustainable and robust. When businesses adopt digitalization in operations, the companies may enhance their efficiencies across operations, streamline their supply chain plans, and overcome and recover with interruptions. The study can be very valuable to companies, policymakers and supply chain managers in quest to increase their resilience and gain better profits through digital innovation.

4.9 Combined Affect

Table 4.8 Combined Affects

Variables	Coefficient B	Std. Error	Beta	t value	P value	LLCI-ULCI	Significant
Supply chain resilience	0.598	0.063	0.664	9.515	0.000	[0.471, 0.725]	Significant
Supply chain viability	0.734		0.619	7.210	0.000	[0.529, 0.940]	Significant
Digitalization	-0.096	0.091	-0.095	-1.055	0.297	[-0.280, 0.088]	Not Significant

Note. N = 47. SE = Standard Error; Beta = Regression Coefficient; t = t-value; p = p-value; LLCI = Lower level confidence interval; ULCI = Upper level confidence interval. $p < .05$*, $p < .01$**, $p < .001$***

The performed regression analysis presented in Table 4.8 that has demonstrated the combined effect of supply chain viability and resilience has the beneficial impact on the supply chain performance. According to the results obtained, the resilience and supply chain viability are quite favorable impact which strongly influences the supply chain performance. With regard to supply chain performance, this is validated by the regression coefficients of B = 0.598 ($p < 0.001$) and B = 0.734 ($p < 0.001$), respectively. These results help highlight the importance of resilience and viability in improving the overall performance of supply chain operations. Businesses that constantly improve their supply chain while maintaining operational viability will become more efficient, achieve better operational results, and be more flexible in reacting to market disturbances. The strong statistical relationship supports these findings.

Since it enables a business to withstand disruptions and bounce back from them, supply chain resilience is an essential component of maintaining supply chain performance. Thus the definition of supply chain resilience is "the capacity of a strong supply chain to predict, adapt to, and recover from unexpected events, including shortages in supplies, logistics delays, or fluctuations in market demand." Resilience has a positive and significant influence on performance; thus, companies

that invest in resilient strategies—such as diversifying their suppliers, applying risk management techniques, and supporting cooperation throughout the supply chain—are more likely to be able to continue their operations and maintain their competitive advantages even in volatile surroundings.

Supply chain viability also plays an important role in ensuring the success of the entire chain, on a long term basis. What does "viability" mean? Supply chain viability refers to the capacity of supply chain to be running, economically viable over a longer period of time. The potential guarantees that the firms can proceed to operate effectively in spite of the fact that the condition of the market is never stable. In the context of the supply chain management, the critical role that viability plays with regard to its performance underscores the importance of strategic planning, economy of resources and projects such as sustainability. When a firm considers the viability of the firm as the top priority through excellent financial management, infrastructure investments and sustainable performance, the probabilities of continued growth and success in its operations increase.

Nonetheless, the results of the study did not prove the considerable direct impact of digitalization on the efficiency of supply chains operations. According to the regression analysis results, B = -0.096 and B p = 0.297 is the coefficient of digitalization. This implies that there is no statistical significance of the coefficient. Based on this, it would appear that the direct impact of technology on performance was not the key factor among the importance of digitalization in managing the modern supply.

Digitalization, as used in supply chain management, is the application of modern technologies including artificial intelligence, automation, blockchain, and real-time data analysis. While these instruments present significant opportunities to enhance supply chain operational processes, their effectiveness hinges on their application and utilization. Digitalization might, for instance, increase supply chain visibility, simplify decision-making, and speed logistical operations; but, if there is a weak foundation of resilience and viability, the advantages of digitalization might not be fully appreciated. According to this conclusion, businesses must closely align their digital transformation efforts with a comprehensive supply chain strategy to maximize their effectiveness.

The collinearity table which addresses the reasonable threshold on tolerance, and on variance inflation factor (VIF) explains that there is no multicollinearity in the model. Multicollinearity is when two or more independent variables that are strongly related and interferes with each other. The effect can occur on the results of some variables interpretation. The results in the given study are accurate and individual impact of resilience, viability, and digitalization on supply chain performance by removing multicollinearity.

In future studies, roles of artificial intelligence, blockchain, internet of things and the provision of chain performance must be discussed separately. It is proposed to redesign the supply chain adopted by the firms, which want to optimize the performance and concentrate on the viability. This involves them being increasingly self-sufficient optimizing resources thus will be more stable in financial terms and undertaking activities which are most likely to guarantee their survival in the long run. Digital transformation is both as necessary and crucial to the current supply chains as it will be able to facilitate and underpin the already-decided durability and dependability plans.

Upon thorough examination, the regression analysis provides valuable insights regarding the factors influencing the performance of supply chain operations. The resilience and viability of supply chains maintain considerable influence, making it essential to develop sustainable and robust supply chain systems. Although digitalization had no direct influence on performance in this study, it is still a necessary component of modern supply chains, and it should be explored more in several environments. The results of this research contribute to the existing literature on supply chain management and offer valuable insights for organizations seeking to enhance their operational efficiency.

4.10 Hypotheses Testing Results

This section demonstrates the results of hypothesis testing that was done to determine the assumed relationships between supply chain resilience, supply chain viability, digitalization, and supply chain performance.

Table 4.9 Hypotheses Testing Results

Hypothesis	Relationship Tested	Statistical Technique	β / Effect	p-value	Decision
H1	Supply Chain Resilience → Supply Chain Performance	Regression Analysis	β = 0.598	p < 0.05	**Supported**
H2	Supply Chain Resilience → Supply Chain Viability	Regression Analysis	β = 0.087	p > 0.05	**Not Supported**
H3	SCR → SCV → SCP (Mediation)	Hayes PROCESS Model 4	Indirect Effect = 0.0649 (CI includes zero)	p > 0.05	**Not Supported**
H4	Digitalization × SCR → SCV (Moderation)	Hayes PROCESS Model 1	Interaction β = 0.2956	p < 0.05	**Supported**

Note. N = 47. SCR = Supply Chain Resilience; SCV = Supply Chain Viability; SCP = Supply Chain Performance. *p* < .05*, *p* < .01**, *p* < .001***

Table 4.9 presents the hypothesis testing results. The results indicates that the resilience of the supply chain in terms of supply chain performance is significant and positive (b = 0.598, p < 0.001), which in turn support H1. This observation indicates that more resilient organizations have better chances of sustaining and improving their supply chain performance in disruption time. Nonetheless, the one-on-one correlation between supply chain resilience and supply chain viability turned out to be statistically non-significant (p > 0.05); hence, H2 was not confirmed. Moreover, the supply chain viability, as a mediator that was used to find the relationship between the supply chain resilience and the supply chain performance, was analyzed based on Hayes PROCESS Model 4. It showed that the confidence interval of the indirect

effect contained the zero, which meant that the mediation effect was insignificant, so the H3 was not supported. Conversely, digitalization was determined to play a significant moderating role. H4 was supported by the interaction term between supply chain resilience and digitalization presented having a positive significant impact on the supply chain viability ($b = 0.2956$, $p < 0.05$). This finding proves that digitalization enhances the correlation between resilience and viability, and firms are capable of adjusting and maintaining their supply chains in the face of uncertainty.

4.11 Discussion

It becomes obvious that there is a strong positive correlation estimate that the power of association between the two, supply chain resilience (SCR) and supply chain performance (SCP) is 0.712, $p < 0.01$. This result supports the theory that performance directly increases with a higher degree of resilience in supply chain networks. The fact that our SCR outperforms SCP is consistent with the study by (Ivanov, 2020), who stated that resilient supply chains perform better under disruptions. This research is associated with the findings of the earlier research studies carried out by (Wieland and Durach, 2021) that revealed the essential role of resilience in reducing disruptions and proceeding with its operations. This result also supports the argument of (Li et al., 2017) that resilience improve performance. Supply chain resilience is one of the essential phenomena that must be taken into account in a bid to ensure smooth and effective operation even in the adverse conditions. Businesses that build resilience in their supply chains will be more suited to manage uncertainty—that is, swings in the market, natural disasters, and geopolitical disturbances. The statistically significant positive link found in this research emphasizes the need for resilience strategies, including diversity, redundancy, and flexible logistics, to increase the effectiveness of supply chain operations.

Furthermore, it is noteworthy that the low positive correlation existing between SCR and digitalization ($r = 0.331$, $p = 0.05$) denotes the extent to which technology improvements contribute to resilience in a favorable manner. Digital technologies, i.e., real-time tracking, artificial intelligence (AI), and blockchain technology, are useful to build resilience in supply chains along with flexibility (Ivanov et al., 2021). The benefits of digitalization include promoting an increased degree of transparency, making the decision-making process easier, and further

improving the connection between supply chain partners. Although digitalization seems to be a contributor to resilience, the fairly minor correlation indicates that other elements could also be somewhat important in the process of building it. The results shows that higher levels of digitalization improve transparency, innovation, connectivity that improves performance (Culot et al., 2020). The other aspects such as legislative framework, supply chain cooperation, and commitment of leadership are interventions that future research could consider in order to get a better understanding of the processes involved in the resilience development.

The poor and statistically non-significant relationship between supply chain resilience (SCR) and supply chain viability (SCV) implies that resilience, in itself, may not be quite enough to guarantee its viability. The conclusion indicates the gap in the literature which demands additional researches. A supply chain can be subject to a set of issues that can impact its viability. There is low correlation and this implies that despite the fact that resilience manages adverse short term shocks, it may not necessarily be able to maintain survival in overtime perspective unless resilience is coupled with the aspect of strategic planning and investment in sustainable business practices. This can be said even in situations where resilience prevents short-lived disruptions.

Besides, the high interrelationship between and among and digitalization and supply chain viability (SCV) ($r = 0.642$, $p < 0.01$) and supply chain performance (SCP) ($r = 0.521$, $p < 0.01$) have demonstrated that the digital technology while applying to supply chain may significantly influence supply chain performance. This observation can be contrasted with results of (Sjoerdsma & van Weele, 2015), these authors showed the ability of the digital technology to make the results more enhanced and simplify the operations. Within the framework of the modern supply chain management, digitalization is needed to boost its supply chain by ensuring efficiency or cost-reduction and real-time performance monitoring. The correlation between viability and digital tools are extremely high. The reduction of wastage, optimization of the resources allocation process and the improvement of decision making processes, the digital tools not only are a contributor to the generosity of the operational processes, but also to success in long-term sustainability. Another great role played by the digital technologies in ensuring that there is performance although

in keeping with the ever-evolving business environment and the competitiveness setting is the fact that the technologies enhance the performance.

Last, great correlation between supply chain Performance (SCP) - Supply Chain Viability (SCV) ($r = 0.643$, $p = 0.01$) shows the relationship of the viability and performance. This result supports the findings of (Ivanov, 2021), who demonstrated that viability of a sustainable supply chain is key to its success in the long run. A viable supply chain also means that this operation will be not only viable financially, but sustainable operationally as well and will have one consistent performance in the long run (Ivanov, 2021). Businesses that invest in green logistics, circular economy models, responsible sourcing has a superior chance of being long term profitable, and mitigating the risks that are associated with resource depletion and legal non-compliance.

Regression analysis clarifies 50.6% of the variance in SCP ($R2 = 0.506$, $p < 0.001$), therefore confirming the relevance of SCR as a potential indicator of SCP. The existence of this significant positive correlation emphasizes the need to build strong supply chain resilience since they will greatly enhance performance. These results line up with (Ponomarov & Holcomb, 2009) observations, which underlined resilience as a main driver of supply chain competitiveness. More proof of how strong these findings are comes from the important statistics of the model ($F (1, 44) = 45.139$, $p < 0.001$) and the confidence interval (0.449 to 0.834). These kinds of findings emphasize the need to give resilience top priority in supply chain strategies if we want to get the best performance from the supply chain. Organizations that can proactively enhance resilience-building measures, assessment system of risks, supply chain mapping, and better planning, will be more successful in mitigating the interruptions and in retaining continuity of organizational operations.

Although, SCR has a significant influence on SCP ($B = 0.5766$, $p < 0.001$) and the mediation analysis shows less mediating effect of the SCV in this relationship in regards to the analysis context. The indirect effect is 0 within the bootstrapped confidence interval -0.0911 -0.1890. This result indicates that there is no mediation of the relationship. The results demonstrate that SCV does not mediate the relationship. The findings suggest that, while viability might require additional context to mediate effectively, resilience and performance have a more direct connection.

Notwithstanding this, the combined model that explains SCP is quite significant ($R2 = 0.8157$, $p < 0.001$), meaning that resilience and viability taken together have a major influence over performance.

The moderation analysis highlights digitalization as the primary moderator in the relationship between SCR and SCV. Supply chain resilience (SCR) and digitalization (coefficient = 0.2956, p = 0.00247) have a positive correlation; digitalization significantly influences supply chain viability (SCV) (coefficient = 0.5719, p = 0.001). These results imply that adding technology into supply chains raises their feasibility. (Ivanov & Dolgui, 2020), who underlined the need for digitalization as a vital facilitator for resilience and viability, support these conclusions. The lack of a direct impact of SCR on SCV (coefficient = -0.0716, p = 0.4483) provides additional evidence that digitalization plays a crucial role. The significant indirect effect (coefficient = 0.1691, bootstrapped 95% confidence interval = -0.0252, 0.3369) indicates that digitalization is crucial in modern supply chain systems and confirms its main role in changing the relationship between resilience and viability. The results confirms the statement that digitalization associated with industry 4.0 employed to strengthen supply chain resilience (Xu et al., 2022)

The regression analysis performed on the combined effect of SCR and SCV on SCP reveals clearly that both variables have statistically significant positive effects ($B = 0.598$, $p < 0.001$, and $B = 0.734$, $p < 0.001$, respectively). This data shows that the there is a significant positive impact of resilience and supply chain viability on supply chain performance. On the other hand, the impact of digitalization on supply chain performance was not statistically significant. The beta coefficient and p-value ($B = -0.096$, $p = 0.297$) suggests that the direct effect of digitalization on supply chain performance is still quite limited. However, digitalization significantly moderates the relationship between resilience and viability. (Gunasekaran et al., 2015) also claim that indirect effects of digitalization and its interplay with other contributing factors need further studies in future. The digitalization significantly acts as moderator and improves supply chain viability and supply chain performance (Xu et al., 2022). The lack of multicollinearity in the model highlights the significance of resilience and viability in supply chain management, hence supporting the credibility of the results.

4.12 Reason of the Non Mediating Effect of Supply Chain Viability

The implication of this finding is that although firms might have implemented some resilience-enhancing practices, such as more responsive, flexible, or disruption-absorbing practices, this has not yet resulted in long-term structural viability that can drive performance. Now the question is why SCV did not mediate the SCR–SCP relationship. The theoretical nuance which is revealed by the non-significant mediation of supply chain viability between resilience and performance is a critical one: viability is not a universal mediator but a conditional capability. This observation is consistent with the modern literature indicating that viability programs tend not to result in performance improvements unless they are implemented in the right contexts (Chowdhury et al., 2021). In particular, (Dubey et al., 2020) report the way investments into viability may exhibit the so-called diminishing returns when applied in the absence of the digital integration frameworks.

This conditional relationship is explained by the significant moderating effect of digitalization, which supports the distinction between the notions of structural and cognitive viability (created by resilience attributes and digital technologies, respectively) by (Ivanov & Dolgui, 2021). According to these scholars, structural factors only generate adaptive potential, and digital technologies furnish the wisdom that is required to transform this potential into performance results. This is why viability only mediates the resilience-performance relationship when digitally enabled- a result that is consistent with the capability amplification hypothesis proposed by (Wamba et al., 2020), where digital transformation fundamentally changes the traditional performance of the traditional supply chain capabilities and value creation. In turn, this study puts important boundary conditions over viability theory, indicating that digital maturity is a key contingency ingredient to the effectiveness of viability as a mediating factor (Rialti et al., 2020).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The findings of this study give a distinct view of the interaction of supply chain performance (SCP), the digitalization, supply chain viability (SCV), and the supply chain resilience (SCR). They demonstrate that the primary driver of improved supply chain performance (SCP) is supply chain resilience (SCR). SCR is positively correlated to SCP with a variance of 50 per cent of the outcome. Businesses that place resilience as the priority will thus have better SCP. To a larger extent, the digitalization might be reducing risk, facilitating SCR, and, at the same time, facilitating SCP. These findings substantiate the evidence of previous studies that led to the continuation of findings that found that digital means could help firms to manage demand better and to maximize profit and capacity to respond to shocks faster.

These lessons tend to imply that the company must be competitive, in the long term and operating in uncertainty. The outcome indicates that the relationship between the supply chain resilience and supply chain viability is enhanced by the presence of the digitalization. The digitalization involves systemization, tracking systems and the state-of-the-art data analysis. Thereby, businesses, which make the investment in digital technology, may go much further to enhance the viability of their supply chain, as well as, the resilience and ability to maintain their supply chain performance in long term disturbance. Alternatively, in this framework, it is possible to consider that the effects of digitalization on SCP are indirect since it could contribute to it indirectly. Nonetheless, the digitalization remains an enabling factor, and it enables businesses to take part in the improved performance. Digitalization can provide the infrastructure and the means to be resilient and viable. This conclusion

suggests the necessity of establishing a strategic framework for digital transformation, ensuring that technological expenditures align with supply chain objectives.

While a significant correlation with SCP was observed, SCV did not strengthen the desired relationship between SCR and SCP. This finding indicates that while SCV plays a role in performance independently, it does not represent the primary mechanism through which resilience influences performance. In other terms, resilience contributes to performance through alternative pathways rather than through viability, although resilient supply networks typically demonstrate a higher level of performance. It can be concluded that the transformation of resilience into enhanced performance might require additional factors such as adaptation, flexibility, or creativity. This hypothesized mediator should be looked at in the next study to help us better understand the processes behind the relationship between SCR and SCV.

Using moderation analysis, it was found that digitalization enhances the effect of SCR on SCV, emphasizing the crucial role of digitalization in supply chain operations. This conclusion indicates that businesses possessing solid digital competencies are more willing to implement resilience strategies to maintain their viability. The implementation of digital tools such as artificial intelligence, blockchain, and real-time monitoring systems enhances the visibility of supply chains, facilitates predictive analytics, and improves decision-making capabilities. Such advancements would contribute to explaining the relationship between resilience and viability. Organizations that exhibit lower levels of digital adoption may encounter challenges in fully realizing the advantages of resilience, given the significant moderating impact of digitalization. Therefore, companies that want to improve their supply chain viability and resilience need to incorporate digital transformation projects into their supply chain plans.

The usage of advanced digital tools has a great influence on supply chain performance, which leads to the importance of viability, digitalization, and resilience as the means of enhancing supply chain performance. The businesses which place immense value to improvement of the overall viability, resilience and digitalization is enhancing the functionality of their supply chain. Such businesses are then better placed to provide consistency in terms of operation in times of uncertainty. The results reveal the fact that more complicated approach to supply chain management

matters. To provide useful information to the policy makers in formulation and implementation.

In addition to funding resilience-building initiatives like risk management and backup plans. Businesses should also concentrate on guaranteeing the advanced digital transformation to ensure long-term viability. It may be accomplished through the implementation of the digital tools in supply chains, their sustainability and financial stability, and the formation of strategic alliances.

These findings highlight the necessity of incorporating resilience, viability, and digital technology into supply chain strategies to better enhance supply chain performance. Supply chains able to effectively manage these three elements will be more suited to withstand long-term disruptions, maintain efficiency, and sustain growth in an external environment getting more complex. However, the weak link seen between SCR and SCV, along with the small direct effect of digitalization on SCP, shows that we need to look deeper into how these factors are connected. Investigation may focus on the distinct elements essential to the industry, the condition of the external market, and the organizational competencies that could influence these relationships in the future. Furthermore, longitudinal research could provide more in-depth understanding of the interactions among resilience, viability, and digitalization throughout time to influence supply chain operations. Building on these results, future studies will help provide a more complete understanding of supply chain performance dynamics. This can be accomplished by broadening the scope of the study and incorporating additional variables that are affected by the phenomenon being studied.

The initial research question of the present study was to analyze how supply chain resilience affects the supply chain performance. According to the empirical results, supply chain resilience positively and significantly impacts supply chain performance. It implies that companies, which have greater resilience capacities, can withstand disruptions in a much better way and continue to have better supply chain performance. Thus, the initial research purpose has been fulfilled.

The second objective was to determine how supply chain viability mediates the relationship between supply chain resilience and supply chain performance. The

mediation analysis findings indicate that the supply chain viability is not a significant mediator of this relationship as the indirect relationship was not statistically significant. It means that resilience does positively affect performance, though it is not necessarily mediated by supply chain viability in the considered situation. Therefore, the findings could not be used to support the second research objective.

The third study objective was to investigate how digitalization moderates the association between supply chain resilience and supply chain viability. The results show that digitalization positively reinforces this relationship, which implies that the greater the degree of digitalization, the greater the positive impact of resilience on supply chain viability. This demonstrates the importance of digital technologies in enhancing adaptive and sustainable supply chains. As a result, the third research objective has been met.

The fourth objective aimed at exploring the interplay between supply chain resilience, supply chain viability, and the digitalization in improving supply chain performance. The general results of the research indicate that although the concept of supply chain resilience is a direct factor in enhanced performance, the concept of digitalization significantly contributes to the enhancement of resilience and viability capacity, both of which contribute to long-term supply chain performance. These findings support the fact that a coordinated strategy of resilience and digital transformation is the key to sustainable performance of the supply chain. The fourth research objective is therefore addressed.

5.2 Limitations and Future Research Directions

It is important to consider the several limitations of this study when evaluating the findings. Future studies should consider the longitudinal study between supply chain viability, digitalization, resilience and supply chain performance. The cross sectional approach did not shows the results of the relationship over time.

Furthermore, the other sectors and sample size may limit the findings of this study. Also the result may not accurately reflect complex global supply chain and other industries. This study did is only based on Pakistani market, that may limit the results according to global market. Future study should focus on global market. The bias may occur due to some companies didn’t provide access to data. The

generalization of digitalization may ignore the unique effect of particular technologies.

Future studies should be focused on the unique impact of Ai, block chain, internet of things, and big data analytics. Furthermore, the lack of studies resources may make it difficult to examine every aspect of the variables affecting supply chain performance. Apart from such limitations, the study offers significant result of the relationship among supply chain resilience, digitalization, viability, and the performance of supply chain.

Future studies should consider other mediators such as supply chain agility, collaborating with partners; leadership, competency and sustainability need to be investigated further. Partner integration facilitates integration in the supply chain system through system synchronization, objectives alignment and efficient communication between partners. The supply chains can strengthen their flows and can withstand disturbances through combating their resources, setting strategic programs, and dependable collaborations.

The parameters developed by a strong leadership are flexibility, strategic vision and quick decision-making. This is required to address the dynamics surrounding the supply chain in the case of disruption. The knowledge as a group and the work experience of the supply chain professionals are very high and increase the level of resilience. Responding to disruption and making complex emergency mitigation ready is also the responsibility of a well trained work force capable of anticipating danger.

Sustainability can be achieved in the long term through the integration of environmental, social and financial elements into the governments of the supply chains. All these together are results in high performance of the supply chain. This approach that will enable comprehension of these notions independently of their impact on the overall output of the supply chain will enable the analysis of resilience as the possible mediators. The future studies should focus on consumer behavior, international pandemics, conflicts among nations and religious groups, inflation and financial crisis.

Due to global occurrence, including pandemic and climate changes, international conflicts and cyber-attacks, supply chain performance is severely impacted. This evidences the need to have even stronger supply chain, which would particularly integrate the modern digitalization innovations in order to mitigate the impacts of the disruptions. It will be in a position to build up the refined framework so as to be more accommodating to the broader framework in which the supply chains exist by introducing them into the field of research in the future.

The transformations in the aspects of digitalization, resilience and viability and the corresponding undergo analysis results in the need to use longitudinal research approaches in future. Longitudinal approach would enable pursuing the dynamism and the enhancement of the supply chains performance and resilience over longer time periods amidst continuous disturbance like COVID-19 and war between countries. This approach will result in the overall success of the supply chain. Further information can be gained about how supply chains get into activities aimed at turning digital and how supply chains agendas resilience can be achieved as well as the capability to stay afloat with an extended period of time. Digitalization and resilience were learned and put to practice as they allowed organizations to greatly improve their decision-making and sensitize them to maximize their profitability in the long-run. It is anchored on longitudinal studies with the help of which scholars may express the views on the effect of the digitalization initiatives. Further studies would aid in drawing conclusions on whether the digital technologies bring the benefits in the long-term and whether the digital technologies require continuous adjustment.

The outcomes of such a study will allow seeing the effects of resilience, viability and digitalization on supply chain performance at different times more clearly. Furthermore, carrying out studies relevant to a particular industry will help identify the unique components and difficulties faced in different industries. Future studies focus on real estate, textiles, and healthcare to better educate about the particular influences and difficulties within those industries.

Every sector has unique operational limits and challenges that affect the way resilience and digitalization impact the viability and performance of supply chains. Future research is needed in different sectors, like healthcare, the construction industry, e-commerce, and hotels, to gain more knowledge of the impact of viability

and resilience on the performance of the supply chain. The healthcare sector is one of those that depend on strong supply chains as they ensure the availability of essential medical supplies, particularly during global health crises such as the COVID-19 pandemic.

On the other hand, the industry encounters some obstacles that are pertinent to the production interruptions, dependence on suppliers, and the just-in-time inventory managing systems. Supply chains of the retail industry, particularly that of e-commerce, have to deal with the demand fluctuations of clients, challenges in the last mile logistics, and supply chains visibility challenge. By targeting their research to industries, scholars can focus on viability, digitalization and resilience across the diverse industries in a broad-scoped manner.

Regarding the dynamic, in relation to the sphere of supply chains, it is important to consider potential moderators separately, i.e., artificial intelligence (AI), blockchain, and the Internet of Things (IoT). Artificial intelligence-powered data analytics is beneficial to logistics in order to achieve timely products delivery. Among the key strengths of the AI, there are its ability to forecast the demand variation. It simplifies the manufacturing of supply of goods that leads to the demand by customers. It is artificial intelligence that can thus assist in making superior choices. The blockchain technology is useful in an effort to safeguard the supply chains to the vulnerabilities of sensitive information-breakage. Blockchain technology can improve traceability, security and transparency. Moreover, the tools promote the supply chains to respond swiftly and efficiently concerning several disruptive events. Internet of Things provides ease in real-time monitoring of the environment, transport and logistics and inventory.

These technologies can stimulate development of new ideas which will improve operational efficiency of the supply chains. Further reviews and allocations of attention should be to test the level to what extent these new technologies assured can be used to enhance security and also to establish the relationship between the application of the new technology and the changes in the supply chain operations.

It is also important to take into account such factors as culture and geography that contribute to the supply chain relationships. This is because differences in law

systems, implementation of policies and issues can provide valuable guidance with respect to growth of global supply chain. Companies must take into account the cultural and geographic factors whenever entering new market. Examples of corporate-level cultural attributes which could affect the way companies react to resilience and digitalization is institutional behaviors, the approach of management and risk-taking.

It is possible that multinational companies can align supply chain plan with the host environment more effectively when they have a greater understanding of local cultural and geographic preferences. Best practice, successful project identifications; comparative evaluation between various countries or sectors of the economy can unveil this aspect of resilience, viability and adaptability of digital projects to diverse environments.

Additionally, it may be recommended to expand the boundaries of the supply chain performance and introduce additional comprehensive parameters such as customer satisfaction and environmental sustainability and creative ability. Traditional performance indicators which include financial performance and speed of delivery are not sufficient to capture long-term increased added value of digitalization and resilience. Important tools to ensure efficiency in supply chain are customer satisfaction, reduction of costs, agility, reliability, responsiveness and green supply chain.

The quality of the innovation that the company can produce is bound to one of its capabilities to adjust to restructuring market conditions, come up with novel ideas, and remain competitive in the face of rapid market reorganization. Studies of these broader indicators should be useful to future studies to provide an enhanced measurement of the contribution of digitalization, resilience and viability to sustainability and high-performance of supply chains.

Furthermore, qualitative methods, such as interviews, case studies, and ethnographic research will facilitate measured outcomes in future studies, both due to their ability to provide more insight into the actual application of digitalization and challenges in the process of increasing supply chain resilience. Quantitative research tends to focus on the statistical relationship whereas qualitative methods do not.

However, operational complexity, strategic decision-making processes and real-life events, which cannot be satisfactorily depicted through numbers only, can be discovered through qualitative methods. The functions of interviewing legislators, industry specialists and supply chain managers would assist us to attain first hand knowledge, which is insightful, in order to understand the advantages and limitations of the variables as well as the role the said variables determine in the performance of the supply chain. Examples of the firms that successfully implemented digitalization initiatives and resilience plans may serve as case studies that other companies that entitled to scale up their supply chain capacity could gain some valuable insights to be applied.

In the review of the research, a multidisciplinary approach is needed in the future in order to address the number of problems that contemporary supply chains currently encounter and provide solutions on how companies can go about in a global environment that is increasingly complex and uncertain.

REFERENCES

Ahmad, D., & Afzal, M. (2020).Flood hazards and factors influencing household flood perception and mitigation strategies in Pakistan. *Environmental Science and Pollution Research, 27*(13), 15375-15387. https://doi.org/10.1007/s11356-020-08057-z

Ahmad, M. I., & Ma, H. (2020).An investigation of the targeting and allocation of post-flood disaster aid for rehabilitation in Punjab, Pakistan. *International Journal of Disaster Risk Reduction, 44*, 101402. https://doi.org/10.1016/j.ijdrr.2019.101402

Ali, M. H., Chung, L., Kumar, A., Zailani, S., & Tan, K. H. (2021). A sustainable Blockchain framework for the halal food supply chain: Lessons from Malaysia. *Technological Forecasting and Social Change*, *170*(120870), 120870. https://doi.org/10.1016/j.techfore.2021.120870

Ali, A. A. A., Sharabati, A.-A. A., Allahham, M., & Nasereddin, A. Y. (2024). The relationship between supply chain resilience and digital supply chain and the impact on sustainability: Supply chain dynamism as a moderator. *Sustainability, 16*(7), 3082. https://doi.org/10.3390/su16073082

Alheet, A. F., & Attiany, M. (2025). The impact of digital technology, automation, and data integration on supply chain performance: Exploring the moderating role of digital transformation. *Logistics, 9*(1), 11. https://doi.org/10.3390/logistics9010011

Atieh, A. A., Abu Hussein, A., Al-Jaghoub, S., Alheet, A. F., & Attiany, M. (2025). The impact of digital technology, automation, and data integration on supply chain performance: Exploring the moderating role of digital transformation. *Logistics, 9*(1), 11. https://doi.org/10.3390/logistics9010011

Ambulkar, S., Blackhurst, J., &Grawe, S. (2015). Firm's resilience to supply chain disruptions: Scale development and empirical examination. *Journal of operations management, 33*, 111-122. https://doi.org/10.1016/j.jom.2014.11.002

Apeji, U. D., & Sunmola, F. T. (2020). An Entropy-Based Approach for Assessing Operational Visibility in Sustainable Supply Chain. *Procedia Manufacturing, 51*, 1600–1605. https://doi.org/10.1016/j.promfg.2020.10.223

Araz, O. M., Choi, T., Olson, D. L., & Salman, F. S. (2020). Data Analytics for Operational Risk Management. *Decision Sciences*, *51*(6). https://doi.org/10.1111/deci.12443

Agrawal, N., Sharma, M., & Raut, R. D., et al. (2024). Supply Chain Flexibility and Post-pandemic Resilience. *Global Journal of Flexible Systems Management, 24*(Suppl. 1), 119–138. https://doi.org/10.1007/s40171-024-00375-2

Ardolino, M., Bacchetti, A., &Ivanov, D. (2022). Analysis of the COVID-19 pandemic's impacts on manufacturing: A systematic literature review and future research agenda. *Operations Management Research*, *15*(1-2), 551-566. https://doi.org/10.1007/s12063-021-00225-9

Azadegan, A., & Dooley, K. J. (2020). A typology of supply network resilience strategies: complex collaborations in a complex world. *Journal of Supply Chain Management, 57*(1), 17–26. https://doi.org/10.1111/jscm.12256

Azadegan, A., Mellat Parast, M., Lucianetti, L., Nishant, R., & Blackhurst, J. (2020). Supply Chain Disruptions and Business Continuity: An Empirical Assessment. Decision Sciences, 51(1), 38–73. https://doi.org/10.1111/deci.12395

Bevilacqua, M., Ciarapica, F. E., & Marcucci, G. (2018).A modular analysis for the Supply Chain Resilience Triangle. *IFAC-PapersOnLine*, *51*(11), 1528-1535. DOI not available

Bier, T., Lange, A., & Glock, C. H. (2020). Methods for mitigating disruptions in complex supply chain structures: a systematic literature review. *International Journal of Production Research*, *58*(6), 1835–1856. https://doi.org/10.1080/00207543.2019.1707204

Benbarrad, T., Salhaoui, M., Kenitar, S. B., & Arioua, M. (2021). Intelligent Machine Vision Model for Defective Product Inspection Based on Machine Learning. *Journal of Sensor and Actuator Networks*, *10*(1), 7. https://doi.org/10.3390/jsan10010007

Baryannis, G., Dani, S., & Antoniou, G. (2019). Predicting supply chain risks using machine learning: The trade-off between performance and interpretability. *Future Generation Computer Systems*, *101*, 993–1004. https://doi.org/10.1016/j.future.2019.07.059

Baryannis, G., Dani, S., & Antoniou, G. (2019). Predicting supply chain risks using machine learning: The trade-off between performance and interpretability. *Future Generation Computer Systems*, *101*, 993–1004. https://doi.org/10.1016/j.future.2019.07.059

Bali, N., & Singla, A. (2021). Emerging Trends in Machine Learning to Predict Crop Yield and Study Its Influential Factors: A Survey. *Archives of Computational Methods in Engineering*. https://doi.org/10.1007/s11831-021-09569-8

Brusset, X., Ivanov, D., Jebali, A., Davide La Torre, & Repetto, M. (2023). A dynamic approach to supply chain reconfiguration and ripple effect analysis in an epidemic. *International Journal of Production Economics, 263*(108935), 108935–108935. https://doi.org/10.1016/j.ijpe.2023.108935

Büyüközkan, G., & Göçer, F. (2018). Digital Supply Chain: Literature Review and a Proposed Framework for Future Research. *Computers in Industry*, *97*(1), 157–177. https://doi.org/10.1016/j.compind.2018.02.010

Cappelli, A., &Cini, E. (2020). Will the COVID-19 pandemic make us reconsider the relevance of short food supply chains and local productions?. *Trends in food science & technology*, *99*, 566. https://doi.org/10.1016/j.tifs.2020.03.041

Chauhan, V. K., Perera, S., & Brintrup, A. (2020). The relationship between nested patterns and the ripple effect in complex supply networks. *International Journal of Production Research*, *59*(1), 325–341. https://doi.org/10.1080/00207543.2020.1767026

Christopher, M., & Peck, H. (2004). Building the Resilient Supply Chain. *International Journal of Logistics Management, 15*(2), 1–13. https://doi.org/10.1108/09574090410700275

Chowdhury, P., Paul, S. K., Kaisar, S., & Moktadir, M. A. (2021). COVID-19 pandemic related supply chain studies: A systematic review. *Transportation Research Part E: Logistics and Transportation Review, 148*, 102271. https://doi.org/10.1016/j.tre.2021.102271

Chowdhury, M. M. H., & Quaddus, M. (2017). Supply chain resilience: Conceptualization and scale development using dynamic capability theory. *International Journal of Production Economics, 188*, 185-204. https://doi.org/10.1016/j.ijpe.2017.03.020

Chowdhury, P., Paul, M., Kaisar, S., & Moktadir, M. A. (2025). A systematic literature review on flexible strategies and performance indicators for supply chain resilience. *Global Journal of Flexible Systems Management, 26*(3), 207–231. https://doi.org/10.1007/s40171-024-00415-x

Colombari, R., Geuna, A., Helper, S., Martins, R., Paolucci, E., Ricci, R., &Seamans, R. (2023). The interplay between data-driven decision-making and digitalization: A firm-level survey of the Italian and US automotive industries. *International Journal of Production Economics, 255*, 108718. https://doi.org/10.1016/j.ijpe.2022.108718

Carbonneau, R., Laframboise, K., & Vahidov, R. (2008). Application of machine learning techniques for supply chain demand forecasting. *European Journal of Operational Research, 184*(3), 1140–1154. https://doi.org/10.1016/j.ejor.2006.12.004

Cadden, T., Millar, K., Treacy, R., & Humphreys, P. (2020). The mediating influence of organisational cultural practices in successful lean management implementation. *International Journal of Production Economics, 229*, 107744. https://doi.org/10.1016/j.ijpe.2020.107744

Culot, G., Nassimbeni, G., Orzes, G., & Sartor, M. (2020). Behind the definition of Industry 4.0: Analysis and open questions. *International Journal of Production Economics, 226*, 107617. https://doi.org/10.1016/j.ijpe.2020.107617

Dolgui, A., Ivanov, D., & Sokolov, B. (2020). Reconfigurable supply chain: the X-network. *International Journal of Production Research, 58*(13), 4138–4163. https://doi.org/10.1080/00207543.2020.1774679

Dubey, R., Gunasekaran, A., Bryde, D. J., Dwivedi, Y. K., & Papadopoulos, T. (2020). Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting. *International Journal of Production Research, 58*(11), 3381–3398. https://doi.org/10.1080/00207543.2020.1722860

Dubey, R., Bryde, D. J., Foropon, C., Tiwari, M., Dwivedi, Y., & Schiffling, S. (2021). An investigation of information alignment and collaboration as complements to supply chain agility in humanitarian supply chain. *International Journal of Production Research, 59*(5), 1586-1605. https://doi.org/10.1080/00207543.2020.1865583

Legg, M., Silver, R. A., & Park, S. (2025). Weathering the Storm: Dynamic Capabilities and Supply Chain Agility in Supply Chain Resilience. *Logistics*, *9*(4), 136. https://doi.org/10.3390/logistics9040136

Dash, S., Shakyawar, S. K., Sharma, M., & Kaushik, S. (2019). Big data in healthcare: Management, analysis and future prospects. *Journal of Big Data*, *6*(1), 1–25. springer. https://doi.org/10.1186/s40537-019-0217-0

Fosso Wamba, S., & Akter, S. (2019). Understanding supply chain analytics capabilities and agility for data-rich environments. *International Journal of Operations & Production Management*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/ijopm-01-2019-0025

Faruquee, M., Paulraj, A., &Irawan, C. A. (2021). Strategic supplier relationships and supply chain resilience: is digital transformation that precludes trust beneficial?. *International Journal of Operations & Production Management*, *41*(7), 1192-1219. https://doi.org/10.1108/IJOPM-10-2020-0702

Gu, T., Dolan-Gavitt, B., & Garg, S. (2017). BadNets: Identifying Vulnerabilities in the Machine Learning Model Supply Chain. *ArXiv (Cornell University)*. https://doi.org/10.48550/arxiv.1708.06733

Gunasekaran, A., Subramanian, N., & Rahman, S. (2015). Supply chain resilience: Role of complexities and strategies. *International Journal of Production Research*, *53*(22), 6809–6819. https://doi.org/10.1080/00207543.2015.1093667

Hennelly, P. A., Srai, J. S., Graham, G., &FossoWamba, S. (2020). Rethinking supply chains in the age of digitalization. *Production Planning & Control*, *31*(2-3), 93-95. https://doi.org/10.1080/09537287.2019.1631469

Ho, W. R., Tsolakis, N., Dawes, T., Dora, M., & Kumar, M. (2022). A digital strategy development framework for supply chains. *IEEE Transactions on Engineering Management*. https://doi.org/10.1109/TEM.2021.3131605

Harbour, L. (2020). The coronavirus impact on the global automotive supply chains. *Retrieved from Forbes:* https://www.forbes.com/sites/laurieharbour1/2020/03/13/the-coronavirus-impact-on-the-global-automotive-supply-chain.

Hosseini, S. A., Moghaddam, A., Damganian, H., & Shafiei Nikabadi, M. (2021). The Effect of Perceived Corporate Social Responsibility and Sustainable Human Resources on Employee Engagement with the Moderating Role of the Employer Brand. *Employee Responsibilities and Rights Journal*, 34. https://doi.org/10.1007/s10672-021-09376-0

Hajarath, K., & Vummadi, J. (2024). Enhancing supply chain resilience: Proactive strategies for disruptive events. *International Journal of Supply Chain Management*, *9*(3), 1-11. https://doi.org/10.47604/ijscm.2633

Hofmann, E. and Langner, D. (2020), "The Rise of Supply Chain Viability – Digital Solutions as a Boosting Role", December, pp. 1–14. https://doi.org/10.13140/RG.2.2.34859.26405

Huang, M., & Rust, R. T. (2023). The Caring Machine: Feeling AI for Customer Care. *Journal of Marketing*, *88*(5). https://doi.org/10.1177/00222429231224748

Hussain, M., Butt, A. R., Uzma, F., Ahmed, R., Irshad, S., Rehman, A., &Yousaf, B. (2020). A comprehensive review of climate change impacts, adaptation, and mitigation on environmental and natural calamities in Pakistan. *Environmental monitoring and assessment*, *192*, 1-20. https://doi.org/10.1007/s10661-019-7956-4

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transportation Research Part E: Logistics and Transportation Review*, *136*, 101922. https://doi.org/10.1016/j.tre.2020.101922

Ireri, D., Belal, E., Okinda, C., Makange, N., & Ji, C. (2019). A computer vision system for defect discrimination and grading in tomatoes using machine learning and image processing. *Artificial Intelligence in Agriculture*, *2*, 28–37. https://doi.org/10.1016/j.aiia.2019.06.001

Ivanov, D. (2021). Digital supply chain management and technology to enhance resilience by building and using end-to-end visibility during the COVID-19 pandemic. *IEEE Transactions on Engineering Management*. https://doi.org/10.1109/TEM.2021.3095193

Ivanov, D., & Keskin, B. B. (2023). Post-pandemic adaptation and development of supply chain viability theory. *Omega*, *116*, 102806. https://doi.org/10.1016/j.omega.2022.102806

Ivanov, D. (2021). Supply chain viability and the COVID-19 pandemic: a conceptual and formal generalisation of four major adaptation strategies. *International Journal of Production Research*, *59*(12), 3535-3552. https://doi.org/10.1080/00207543.2021.1890852

Ivanov, D. (2022). Viable supply chain model: integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic. *Annals of operations research*, *319*(1), 1411-1431. https://doi.org/10.1007/s10479-020-03640-6

Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *International journal of production research*, *58*(10), 2904-2915. https://doi.org/10.1080/00207543.2020.1750727

Ivanov, D., Dolgui, A., Sokolov, B., & Ivanova, M. (2019). Disruption-driven supply chain (re)planning and performance impact assessment with consideration of resilience factors. *International Journal of Production Research*, *57*(10), 3136–3150. https://doi.org/10.1080/00207543.2018.1537318

Ivanov, D., & Dolgui, A. (2021). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control*, *32*(9), 775-788. https://doi.org/10.1080/09537287.2020.1820638

Ivanov, D., Blackhurst, J., & Das, A. (2021). Supply chain resilience and its interplay with digital technologies: Making innovations work in emergency situations. *International journal of physical distribution & logistics management*, *51*(2), 97-103. https://doi.org/10.1108/IJPDLM-06-2020-0213

Irfan, M., Ali, S. T., Ijlal, H. S., Muhammad, Z. (2024). Exploring the synergistic effects of blockchain integration with IoT and AI for enhanced transparency and security in global supply chains. *International Journal of Contemporary Issues in Social Sciences, 3*(1), 1326–1338.

İncekara, R., & İncekara, B. (2024). Effects of economic and geopolitical risks on the supply chain: an econometric analysis. *Journal of Management Marketing and Logistics*, *11*(2), 131-141.

Junaidi, I. (2020). Pakistan virus cases cross 5,000 mark.

Khan, S. A., Kusi-Sarpong, S., Gupta, H., Arhin, F. K., Lawal, J. N., & Hassan, S. M. (2021). Critical factors of digital supply chains for organizational performance improvement. *IEEE Transactions on Engineering Management*.

Kilimci, Z. H., Akyuz, A. O., Uysal, M., Akyokus, S., Uysal, M. O., Atak Bulbul, B., & Ekmis, M. A. (2019). An Improved Demand Forecasting Model Using Deep Learning Approach and Proposed Decision Integration Strategy for Supply Chain. *Complexity*, *2019*, 1–15. https://doi.org/10.1155/2019/9067367.

Khadija Shoukat, Jian, M., Umar, M., Habiba Kalsoom, Wasim Sijjad, Shahid Hussain Atta, & Ullah, A. (2023). Use of digital transformation and artificial intelligence strategies for pharmaceutical industry in Pakistan: Applications and challenges. *Deleted Journal*, *1*(1), 1486–1486. https://doi.org/10.36922/aih.1486

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics*, *231*(107831), 107831. https://doi.org/10.1016/j.ijpe.2020.107831

Li, G., Xue, J., Li, N., &Ivanov, D. (2022).Blockchain-supported business model design, supply chain resilience, and firm performance. *Transportation Research Part E: Logistics and Transportation Review*, *163*, 102773. https://doi.org/10.1016/j.tre.2022.102773

Lücker, F., Timonina-Farkas, A., & Seifert, R. W. (2024). EXPRESS: Balancing Resilience and Efficiency: A Literature Review on Overcoming Supply Chain Disruptions. *Production and Operations Management*. https://doi.org/10.1177/10591478241302735

Liu, M., Li, C., Wang, S., & Li, Q. (2023). Digital transformation, risk-taking, and innovation: Evidence from data on listed enterprises in China. *Journal of Innovation & Knowledge, 8*(1), 100332. https://doi.org/10.1016/j.jik.2023.100332

Lopes de Sousa Jabbour, A. B., Chiappetta Jabbour, C. J., Hingley, M., Vilalta-Perdomo, E. L., Ramsden, G., & Twigg, D. (2020). Sustainability of supply chains in the wake of the coronavirus (COVID-19/SARS-CoV-2) pandemic: lessons and trends. *Modern*

Supply Chain Research and Applications, *2*(3). https://doi.org/10.1108/mscra-05-2020-0011

Lim, M. K., Li, Y., Wang, C., & Tseng, M.-L. (2021). A literature review of blockchain technology applications in supply chains: A comprehensive analysis of themes, methodologies and industries. *Computers & Industrial Engineering*, *154*(107133), 107133. https://doi.org/10.1016/j.cie.2021.107133

Luo, W., Kang, S., & Di, Q. (2025). Global Supply Chain Reallocation and Shift under Triple Crises: A US-China Perspective. *arXiv preprint arXiv:2508.06828*. https://doi.org/10.48550/arXiv.2508.06828

Li, X., Wu, Q., Holsapple, C., & Goldsby, T. (2017). An empirical examination of firm financial performance along dimensions of supply chain resilience. *Management Research Review*, *40(*3), 254-269. https://doi.org/10.1108/MRR-02-2016-0030

Liu, C. L., Shang, K. C., Lirn, T. C., Lai, K. H., &Lun, Y. V. (2018). Supply chain resilience, firm performance, and management policies in the liner shipping industry. *Transportation Research Part A: Policy and Practice*, *110*, 202-219. https://doi.org/10.1016/j.tra.2017.02.004

Llaguno, A., Mula, J., &Campuzano-Bolarin, F. (2022). State of the art, conceptual framework and simulation analysis of the ripple effect on supply chains. *International Journal of Production Research*, *60*(6), 2044-2066. https://doi.org/10.1080/00207543.2021.1999697

Lucker, F., Chopra, S. & Seifert, R. W. (2021). Mitigating product shortages due to disruptions in multi-stage supply chains. *Production and Operations Management*, *30*(4), pp. 941-964. https://doi.org/10.1111/poms.13342

Lin, Y., & Li, S. (2024). Supply chain resilience, ESG performance, and corporate growth. *International Review of Financial Analysis*, *87*, 103763. https://doi.org/10.1016/j.iref.2024.103763

Li, P., Chen, Y., & Guo, X. (2025). Digital transformation and supply chain resilience. *International Review of Financial Analysis, 104033*. https://doi.org/10.1016/j.iref.2025.104033

Mandal, S. (2017). The influence of organizational culture on supply chain resilience: A mediating role of collaboration. International Journal of Production Economics, 188, 85–98.

McKinsey & Company (2020). Building supply-chain resilience. https://www.mckinsey.com/business-functions/operations/our-insights/building-supply-chain-resilience

Min, H. (2019). Blockchain Technology for Enhancing Supply Chain Resilience. *Business Horizons*, *62*(1), 35–45. https://doi.org/10.1016/j.bushor.2018.08.012

Mohammed, A., Shekarabi, S. A. H., & Mavi, R. K. (2025). Supply chain resilience: A critical review of risk mitigation, robust optimisation, and technological solutions.

Global Journal of Flexible Systems Management, 26(3), 681–735. https://doi.org/10.1007/s40171-025-00458-8

Namdar, J., Torabi, S. A., Sahebjamnia, N., & Nilkanth Pradhan, N. (2020). Business continuity-inspired resilient supply chain network design. *International Journal of Production Research*, *59*(5), 1–37. https://doi.org/10.1080/00207543.2020.1744474

Nikookar, E., & Yanadori, Y. (2021). Preparing supply chain for the next disruption beyond covid-19: managerial antecedents of supply chain resilience. *International Journal of Operations & Production Management, 42*(1), 59-90. https://doi.org/10.1108/IJOPM-10-2020-0787

Nikookar, E., &Yanadori, Y. (2022). Forming post-COVID supply chains: does supply chain managers' social network affect resilience?. *International Journal of Physical Distribution & Logistics Management*, *52*(7), 538-566. https://doi.org/10.1108/IJPDLM-10-2020-0360

Narayan, R., & Tidström, A. (2020). Tokenizing coopetition in a blockchain for a transition to circular economy. *Journal of Cleaner Production*, *263*, 121437. https://doi.org/10.1016/j.jclepro.2020.121437

Novak, D. C., Wu, Z., & Dooley, K. J. (2021). Whose resilience matters? Addressing issues of scale in supply chain resilience. *Journal of Business Logistics*, *42*(3), 323-335. https://doi.org/10.1111/jbl.12270

Nandi, S., Sarkis, J., Hervani, A. A., & Helms, M. M. (2021). Redesigning Supply Chains using Blockchain-Enabled Circular Economy and COVID-19 Experiences. *Sustainable Production and Consumption*, *27*, 10–22. https://doi.org/10.1016/j.spc.2020.10.019

Ochieng, A. O. (2018). Supply Chain Resilience and Organizational Performance of Pharmaceutical Manufacturing Companies in Nairobi (Doctoral dissertation, university of nairobi).

Öztürk, C., & Yildizbaşi, A. (2020). Barriers to implementation of blockchain into supply chain management using an integrated multi-criteria decision-making method: a numerical example. *Soft Computing*, *24*. https://doi.org/10.1007/s00500-020-04831-w

Parast, M. M. (2022). Toward a contingency perspective of organizational and supply chain resilience. *International Journal of Production Economics*, *250*, 108667. https://doi.org/10.1016/j.ijpe.2022.108667

Pettit, T. J., Fiksel, J., & Croxton, K. L. (2010). Ensuring supply chain resilience: Development of a conceptual framework. *Journal of Business Logistics, 31*(1), 1–21. https://doi.org/10.1002/j.2158-1592.2010.tb00125.x

Park, S. R., Kim, S. T., & Lee, H.-H. (2022). Green Supply Chain Management Efforts of First-Tier Suppliers on Economic and Business Performances in the Electronics Industry. *Sustainability*, *14*(3), 1836. https://doi.org/10.3390/su14031836

Pettit, T. J., Croxton, K. L., &Fiksel, J. (2013). Ensuring supply chain resilience: development and implementation of an assessment tool. *Journal of business logistics*, *34*(1), 46-76. https://doi.org/10.1111/jbl.12015

Pimenta, M. L., Cezarino, L. O., Piato, E. L., da Silva, C. H. P., Oliveira, B. G., &Liboni, L. B. (2022). Supply chain resilience in a Covid-19 scenario: Mapping capabilities in a systemic framework. *Sustainable Production and Consumption*, *29*, 649-656. https://doi.org/10.1016/j.spc.2021.12.026

Ponomarov, S. Y., & Holcomb, M. C. (2009). Understanding the concept of supply chain resilience. *The International Journal of Logistics Management, 20*(1), 124–143. https://doi.org/10.1108/09574090910954873

Pu, G., Qiao, W., & Feng, Z. (2023). Antecedents and outcomes of supply chain resilience: integrating dynamic capabilities and relational perspective. *Journal of Contingencies and Crisis Management*, *31*(4), 706-726. https://doi.org/10.1111/1468-5973.12419

Queiroz, M. M., Wamba, S. F., Jabbour, C. J. C., & Machado, M. C. (2022). Supply chain resilience in the UK during the coronavirus pandemic: a resource orchestration perspective. *International Journal of Production Economics*, *245*, 108405. https://doi.org/10.1016/j.ijpe.2021.108405

Qahtan, S., Yatim, K., Zulzalil, H., Osman, M. H., Zaidan, A. A., & Alsattar, H. A. (2023). Review of healthcare industry 4.0 application-based blockchain in terms of security and privacy development attributes: Comprehensive taxonomy, open issues and challenges and recommended solution. *Journal of Network and Computer Applications*, *209*, 103529. https://doi.org/10.1016/j.jnca.2022.103529

Rogerson, M., & Parry, G. C. (2020).Blockchain: case studies in food supply chain visibility. *Supply Chain Management: An International Journal*, *25*(5), 601-614. https://doi.org/10.1108/SCM-04-2019-0167

Rossit, D. A., Tohmé, F., &Frutos, M. (2019). Industry 4.0: smart scheduling. *International Journal of Production Research*, *57*(12), 3802-3813. https://doi.org/10.1080/00207543.2018.1520478

Rialti, R., Zollo, L., Ferraris, A., & Alon, I. (2019). Big data analytics capabilities and performance: Evidence from a moderated multi-mediation model. *Technological Forecasting and Social Change*, *149*, 119781. https://doi.org/10.1016/j.techfore.2019.119781

Ruel, S., El Baz, J., Ivanov, D., & Das, A. (2021). Supply chain viability: conceptualization, measurement, and nomological validation. *Annals of Operations Research*, 1-30. https://doi.org/10.1007/s10479-020-03827-9

Ruel, S., El Baz, J., Ivanov, D., et al. (2024). Supply chain viability: Conceptualization, measurement, and nomological validation. *Annals of Operations Research, 335*, 1107–1136. https://doi.org/10.1007/s10479-021-03974-9

Rodríguez, M., & Smith, P. (2024). Breaking the digitalization barrier for SMEs: Barriers and strategies for successful digital transformation. *Journal of Innovation and Entrepreneurship, 13*(1), 1–15. https://doi.org/10.1186/s13731-024-00429-w

Sanka, A. I., Irfan, M., Huang, I., & Cheung, R. C. C. (2021). A survey of breakthrough in blockchain technology: Adoptions, applications, challenges and future research. *Computer Communications, 169*(1), 179–201. https://doi.org/10.1016/j.comcom.2020.12.028

Shekarabi, H. S., Kiani Mavi, R., & Romero Macau, F. (2025). Supply chain resilience: A critical review of risk mitigation, robust optimisation, and technological solutions and future research directions. *Global Journal of Flexible Systems Management*, *26*(3), 681–735. https://doi.org/10.1007/s40171-025-00458-8

Shokouhyar, S., Zarrin, S., & Shokoohyar, S. (2020). Analysing the impact of IT governance on the performance of project-based organisations. *International Journal of Business and Systems Research*, *14*(4), 411. https://doi.org/10.1504/ijbsr.2020.110763

Soleymani, M., & Nejad, M. O. (2018). Supply Chain Risk Management using expert systems. *International Journal of Current Engineering and Technology*, *8*(04). https://doi.org/10.14741/ijcet/v.8.4.12

Sadik, A., & Urban, B. (2017). Combining Adaptive Holonic Control and ISA-95 Architectures to Self-Organize the Interaction in a Worker-Industrial Robot Cooperative Workcell. *Future Internet*, *9*(3), 35. https://doi.org/10.3390/fi9030035

Sultana, S., Paul, N., Tasmin, M., Dutta, A. K., & Khan, S. A. (2024). Analyzing supply chain risks and resilience strategies: A systematic literature review. *Engineering Proceedings*, *76*(1), 41. https://doi.org/10.3390/engproc20240076041

Sarwar, D., & Rye, S. (2025). The impact of the Russia-Ukraine war on global supply chains: a systematic literature review. *Frontiers in Sustainable Food Systems, 9*, 1648918. https://doi.org/10.3389/fsufs.2025.1648918

Sawik, T. (2018). Two-period vs. multi-period model for supply chain disruption management. *International Journal of Production Research, 57*(14), 4502–4518. https://doi.org/10.1080/00207543.2018.1430741

Schneider, S., &Kokshagina, O. (2021). Digital transformation: What we have learned (thus far) and what is next. *Creativity and innovation management, 30*(2), 384-411. https://doi.org/10.1111/caim.12401

Scholten, K., Stevenson, M., & van Donk, D. P. (2020). Dealing with the unpredictable: supply chain resilience. *International Journal of Operations & Production Management*, *40*(1), 1-10. https://doi.org/10.1108/IJOPM-01-2019-0060

Shekarian, M., Reza Nooraie, S. V., & Parast, M. M. (2020). An examination of the impact of flexibility and agility on mitigating supply chain disruptions. *International Journal of Production Economics, 220*(1), 107438. https://doi.org/10.1016/j.ijpe.2019.07.030

Singh, C. S., Soni, G., &Badhotiya, G. K. (2019). Performance indicators for supply chain resilience: review and conceptual framework. *Journal of Industrial Engineering International, 15*, 105-117. https://doi.org/10.1007/s40092-018-0284-0

Sjoerdsma, M., & Weele, van, A. J. (2015). Managing supplier relationships in a new product development context. *Journal of Purchasing and Supply Management, 21*(3), 192-203. https://doi.org/10.1016/j.pursup.2015.02.002

Soni, U., Jain, V., & Kumar, S. (2014). Measuring supply chain resilience using a deterministic modeling approach. *Computers & Industrial Engineering, 74, 11–25.* https://doi.org/10.1016/j.cie.2014.08.021

Srivastava, A., & Dashora, K. (2022). Application of blockchain technology for agrifood supply chain management: a systematic literature review on benefits and challenges. Benchmarking*: An International Journal.*

Sturm, S., Hohenstein, N. O., & Hartmann, E. (2023).Linking entrepreneurial orientation and supply chain resilience to strengthen business performance: an empirical analysis. *International Journal of Operations & Production Management*.

Teece, D. J., Pisano, G., &Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic management journal*, *18*(7), 509-533. https://doi.org/10.1002/(SICI)1097-0266(199710)18:7

Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015). Supply chain resilience: Definition, review, and theoretical foundations for further study. *International Journal of Production Research, 53*(18), 5592–5623. https://doi.org/10.1080/00207543.2015.1037934

Tang, C. S. (2006). Perspectives in supply chain risk management. *International Journal of Production Economics, 103*(2), 451–488. https://doi.org/10.1016/j.ijpe.2005.07.006

Torres, J. F., Hadjout, D., Sebaa, A., Martínez-Álvarez, F., & Troncoso, A. (2020). Deep Learning for Time Series Forecasting: A Survey. *Big Data*, *9*(1). https://doi.org/10.1089/big.2020.0159

Vali-Siar, M. M., &Roghanian, E. (2022).Sustainable, resilient and responsive mixed supply chain network design under hybrid uncertainty with considering COVID-19 pandemic disruption. *Sustainable production and consumption*, *30*, 278-300. https://doi.org/10.1016/j.spc.2021.12.003

Viswanadham, N. (2002). The past, present, and future of supply-chain automation. *IEEE Robotics & Automation Magazine, 9*(2), 48–56. https://doi.org/10.1109/mra.2002.1019490

Vivaldini, M., & de Sousa, P. R. (2021). Blockchain connectivity inhibitors: weaknesses affecting supply chain interaction and resilience. *Benchmarking: An International Journal*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/bij-10-2020-0510

Vanany, I., Ali, M. H., Tan, K. H., Kumar, A., &Siswanto, N. (2021). A supply chain resilience capability framework and process for mitigating the COVID-19 pandemic disruption. *IEEE Transactions on Engineering Management*. https://doi.org/10.1109/TEM.2021.3116068

Wieland, A. (2021). Dancing the Supply Chain: toward Transformative Supply Chain Management: *Journal of Supply Chain Management, 57*(1). https://doi.org/10.1111/jscm.12248

Wichmann, P., Brintrup, A., Baker, S., Woodall, P., & McFarlane, D. (2020). Extracting supply chain maps from news articles using deep neural networks. *International Journal of Production Research*, *58*(17), 1–17. https://doi.org/10.1080/00207543.2020.1720925

Wamba, S. F., & Queiroz, M. M. (2022). A Framework Based on Blockchain, Artificial Intelligence, and Big Data Analytics to Leverage Supply Chain Resilience considering the COVID-19. *IFAC-PapersOnLine*, *55*(10), 2396–2401. https://doi.org/10.1016/j.ifacol.2022.10.067

Wamba, S. F., Dubey, R., Gunasekaran, A., & Akter, S. (2020). The performance effects of big data analytics and supply chain ambidexterity: The moderating effect of environmental dynamism. *International Journal of Production Economics*, *222*, 107498. https://doi.org/10.1016/j.ijpe.2019.09.019

Wieland, A., & Durach, C. (2021). Two perspectives on supply chain resilience. *Journal of Business Logistics, 42*(3), 315-322. https://doi.org/10.1111/jbl.12271

Xu, L., Vrieze, P., Arshad, R., & Oyekola, O. (2022). Enhance supply chain resilience through industry 4.0 - a view of designing simulation scenarios. https://doi.org/10.1109/ICEBE55470.2022.00042

Yu, W., Chavez, R., Liu, Q., &Cadden, T. (2023).Examining the Effects of Digital Supply Chain Practices on Supply Chain Viability and Operational Performance: A Practice-Based View.*IEEE Transactions on Engineering Management*, 1-14. https://doi.org/10.1109/TEM.2022.3156531

Yu, W., Jacobs, M. A., Chavez, R., & Yang, J. (2019). Dynamism, disruption orientation, and resilience in the supply chain and the impacts on financial performance: A dynamic capabilities perspective. *International journal of production economics*, *218*, 352-362. https://doi.org/10.1016/j.ijpe.2019.07.013

Yu, W., Wong, C. Y., Chavez, R., & Jacobs, M. (2023). Surfing with the tides: how digitalization creates firm performance through supply chain entrainment. *International Journal of Operations & Production Management*.

Zekhnini, K., Cherrafi, A., Bouhaddou, I., Benghabrit, Y., & Garza-Reyes, J. A. (2020). Supply chain management 4.0: a literature review and research framework. *Benchmarking: An International Journal*, *28*(2), 465–501. https://doi.org/10.1108/BIJ-04-2020-0156

Zhang, Y., Huo, B., Haney, M. H., & Kang, M. (2022). The effect of buyer digital capability advantage on supplier unethical behavior: a moderated mediation model of relationship transparency and relational capital. *International Journal of Production Economics, 253*, 108603. https://doi.org/10.1016/j.ijpe.2022.108603

Zhao, N., Hong, J., & Lau, K. H. (2023). Impact of supply chain digitalization on supply chain resilience and performance: A multi-mediation model. *International Journal of Production Economics*, *259*, 108817. https://doi.org/10.1016/j.ijpe.2023.108817

Zhan, Y., & Tan, K. H. (2018). An analytic infrastructure for harvesting big data to enhance supply chain performance. *European Journal of Operational Research*, *281*(3). https://doi.org/10.1016/j.ejor.2018.09.018

Zhou, X., Zhu, Q., &Xu, Z. (2023). The role of contractual and relational governance for the success of digital traceability: Evidence from Chinese food producers. *International Journal of Production Economics*, *255*, 108659. https://doi.org/10.1016/j.ijpe.2022.108659

Zhang, Y., Zhao, L., & Xie, J. (2023). The impact of digital transformation on supply chain capabilities and competitive performance. *Sustainability*, *15*(13), 10107. https://doi.org/10.3390/su151310107

Zouari, D., Ruel, S., &Viale, L. (2021). Does digitalising the supply chain contribute to its resilience?. *International Journal of Physical Distribution & Logistics Management*, *51*(2), 149-180. https://doi.org/10.1108/IJPDLM-06-2020-0175

QUESTIONNAIRE

ANALYZING THE INFLUENCE OF SUPPLY CHAIN RESILIENCE ON SUPPLY CHAIN PERFORMANCE: ASSESSING THE MEDIATING AND MODERATING ROLE OF SUPPLY CHAIN VIABILITY AND DIGITALIZATION.

Dear respondent!

I am Waleed Ahmad, MS scholar at department of Management Sciences, National University of Modern Languages, Islamabad. I am working on my research work on the above mentioned topic. You are requested to go through this questionnaire carefully. The first part of the questionnaire consists of demographic information. The remaining part of the questionnaire deals with four variables, supply chain resilience, supply chain viability, supply chain digitalization, and supply chain performance. The information will be kept confidential and will be used only for research purposes. Thank you so much for your time and cooperation.

Instructions:

You are required to give your responses against the options ranging from 1 = strongly disagree to 5 = strongly agree.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Demographic Information:

Gender:

Male	Female

Age:

1	2	3	4	5
30-35	36-40	41-45	46-50	50+

Maximum Education Level: _____

Designation: _____

Work Experience: _____

Name of the Company _____

Supply chain resilience:

Supply chain resilience is "the capacity of a supply chain to persist, adapt, or transform in the face of change

Sr. No	Items	SDA 1	DA 2	N 3	A 4	SA 5
1	Our supply chain can quickly adjust operations when unexpected disruptions occur.					
2	Our supply chain recovers effectively after facing unexpected events (e.g., disruption, delay).					
3	Our supply chain anticipates potential disruption risks and prepares in advance.					
4	Our supply chain maintains essential functions even under severe disruptions.					
5	Our supply chain learns from previous disruptions and improves future responses.					

Digitalization (Moderator):

Digitalization is the transformation of processes and methods to improve productivity, efficiency, and reliability using digital technology.

Sr. No	Items	SDA 1	DA 2	N 3	A 4	SA 5
1	Our company uses digital technologies (e.g., AI, IoT, Big Data, blockchain) to support supply chain operations.					
2	Digital technologies enhance information flow and communication across our supply chain.					
3	Digital tools help improve decision-making speed and accuracy in supply chain management.					
4	Our supply chain processes are increasingly automated due to digital technology adoption.					
5	Digitalization has improved visibility and real-time tracking across supply chain partners.					

Supply chain viability (Mediator):

A company capacity to sustain itself over an extended period of time in a changing environment by redesigning its organizational structures and preparing its long-term economic outcomes.

Sr. No	Items	SDA 1	DA 2	N 3	A 4	SA 5
1	Our supply chain can adjust its structure quickly in response to long-term changes.					
2	Our supply chain can reconfigure operational resources to continue functioning in volatile environments.					
3	Our supply chain maintains stable performance despite persistent disruptions.					
4	We adapt our supply network (suppliers, processes, logistics) to maintain continuity when conditions change.					
5	Our supply chain’s long-term survival is supported by proactive adaptation and redesign efforts.					

Supply Chain Performance:

Supply Chain Performance refers to the extended supply chain's activities in meeting end-customer requirements, including product availability, on-time delivery, and all the necessary inventory and capacity in the supply chain to deliver that performance in a responsive manner.

Sr. No	Items	SDA 1	DA 2	N 3	A 4	SA 5
1	Our supply chain consistently meets customer delivery requirements even under pressure.					
2	Our supply chain achieves better cost efficiency due to improved processes.					
3	Our supply chain responds quickly to changes in customer demand.					
4	Our supply chain maintains high quality and reliability in product/service delivery.					
5	Overall, our supply chain performance has improved over time.					