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Advanced Technologies and the Management of Disruptive Supply Chains

The Post-COVID Era

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To my mother, Fazeelat Begum, who defied all odds and overcame limited resources to provide me with the best of education and much more that shaped me into who I am today. You are my inspiration and my strength, and I dedicate this work to you with love and gratitude.

—Hassan Qudrat-Ullah

To my loving parents, Syed Qaiser Ali and Zubaida Shahnaz, my beloved wife, Saadia Khurshid, and children, Mariam, Mustafa, and Aamina. My family has always been a source of strength and the center of my world. Thank you for your love, patience, and encouragement. The book is dedicated to you with all my love and gratitude.

—Syed Imran Ali

Preface

Supply chain management (SCM) is a vital function that affects the performance and competitiveness of any organization. SCM involves the coordination and integration of various activities and processes across the supply chain, from the source to the customer, to deliver value to the end users. SCM is also a complex and dynamic system that faces many challenges and uncertainties due to various internal and external factors, such as demand fluctuations, supply disruptions, environmental regulations, geopolitical risks, and technological changes.

The COVID-19 pandemic has exposed the vulnerability and fragility of many supply chains around the world. The pandemic has disrupted the normal operations of many industries and sectors, causing severe impacts on the economy, society, and environment. The pandemic has also highlighted the need for more resilient and sustainable supply chains that can cope with unexpected shocks and disruptions, adapt to changing customer needs and preferences, and minimize the negative impacts on the triple bottom line of people, planet, and profit.

To achieve this goal, SCM needs to leverage advanced technologies that can enable more agile, responsive, and sustainable supply chain operations. These technologies include artificial intelligence (AI), blockchain, cloud computing, the Internet of things (IoT), and robotics. These technologies have the potential to transform SCM by enhancing the efficiency, effectiveness, transparency, traceability, security, and innovation of supply chain processes and activities. These technologies can also help SCM to improve decision making, collaboration, communication, and learning across the supply chain network.

However, these technologies also pose many challenges and uncertainties for SCM. These include the technical complexity, cost, scalability, interoperability, compatibility, reliability, and security of these technologies. These also include the organizational, managerial, behavioral, ethical, legal, social, and environmental implications of these technologies. Therefore, SCM needs to understand the benefits, challenges, opportunities, and best practices of applying these technologies in different contexts and situations.

This book aims to provide such an understanding by exploring how these advanced technologies can help SCM to manage disruptive supply chains and achieve resilience

in the post-COVID era. The book covers five global manufacturing sectors: automotive, electronics, food and beverages, apparel, and pharmaceutical. These sectors are selected because they represent different types of products (discrete versus continuous), processes (make-to-stock versus make-to-order), markets (mass versus niche), and customers (business-to-business versus business-to-consumer). The book also covers different aspects and functions of SCM such as procurement, production, distribution, inventory, and logistics. These aspects and functions are selected because they represent different stages, flows, and decisions in the supply chain.

The book is organized into eleven chapters that review the current state of the art and practice of SCM regarding these advanced technologies, identify the benefits, challenges, opportunities, and best practices of applying these technologies in SCM, provide empirical evidence and case studies from various industries and contexts on how these technologies can improve SCM performance and resilience, and offer practical recommendations and guidelines for SCM practitioners, policymakers, and stakeholders on how to implement these technologies effectively and efficiently.

The book is intended for a broad audience of academics, researchers, students, practitioners, policymakers, and anyone interested in learning more about how these advanced technologies can enhance SCM in the post-COVID era.

The book is also suitable for use as a textbook or reference book for courses or programs related to SCM, operations management, information systems, technology management, or innovation management.

We hope that this book will provide valuable insights and knowledge for our readers and stimulate further research and practice on this important topic. We also hope that this book will contribute to the advancement of SCM theory and practice in the post-COVID era.

We would like to thank our contributors for their excellent work and dedication in writing their chapters. We would also like to thank our reviewers for their constructive feedback and suggestions that helped us improve the quality of this book.

We are grateful to our publisher for their support and guidance throughout this project.

Finally, we would like to thank our families, friends, and colleagues for their encouragement and support.

Toronto, Canada — Hassan Qudrat-Ullah
Huddersfield, UK — Syed Imran Ali
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Part I
Introduction

Chapter 1
An Overview of Advanced Technologies for the Management of Disruptive Supply Chains

Hassan Qudrat-Ullah

Abstract Supply chain management (SCM) is the process of planning, coordinating, and controlling the flow of materials, information, and services from the source to the customer. SCM faces many challenges and uncertainties due to various factors such as demand fluctuations, supply disruptions, environmental regulations, geopolitical risks, and technological changes. This book examines how advanced technologies such as artificial intelligence, blockchain, cloud computing, the internet of things, and robotics can enhance supply chain management (SCM) in the post-Covid era. It focuses on five global manufacturing sectors and covers various SCM functions and aspects. It reviews the current literature and practice, identifies the benefits, challenges, opportunities, and best practices of using these technologies in SCM, provides empirical evidence and case studies from different industries and contexts, and offers practical recommendations and guidelines for SCM stakeholders. The book aims to help SCM practitioners, policymakers, and researchers to manage disruptive supply chains and achieve resilience.

Keywords Supply chain management · Customer satisfaction · Competitive advantage · Supply disruptions · Environmental regulations · Geopolitical risks · Technological changes · Resilience of supply chains · COVID-19 pandemic · Predictive analytics · Artificial intelligence · Blockchain · Control tower approach

1.1 Introduction

Supply chain management (SCM) is the process of planning, coordinating, and controlling the flow of materials, information, and services from the source to the customer. SCM is essential for creating value, enhancing customer satisfaction, and gaining a competitive advantage in today's global and dynamic business environment

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(Lambert et al. 1998). However, SCM also faces many challenges and uncertainties due to various factors such as demand fluctuations, supply disruptions, environmental regulations, geopolitical risks, and technological changes. These factors can have significant impacts on the performance, efficiency, and resilience of supply chains, especially in times of crisis such as the COVID-19 pandemic (Ivanovet al. 2020).

To cope with these challenges and uncertainties, SCM needs to leverage advanced technologies that can enable more agile, responsive, and sustainable supply chain operations. Advanced technologies refer to the innovative applications of digital, physical, and biological systems that can transform the way supply chains are designed, executed, monitored, and optimized. Some examples of advanced technologies for SCM include:

- *Supply chain resilience*: The ability of a supply chain to recover from disruptions and maintain its functionality and performance. Supply chain resilience can be enhanced by using technologies such as predictive analytics, artificial intelligence (AI), blockchain, and control tower approach that can provide better visibility, coordination, risk management, and contingency planning across the supply chain network (Hohenstein et al. 2015; Wieland et al. 2017).
- *Smart manufacturing*: The integration of advanced manufacturing technologies such as robotics, automation, additive manufacturing (3D printing), internet of things (IoT), big data analytics, cloud computing, and fog computing that can enable more efficient, flexible, and customized production processes. Smart manufacturing can improve the quality, productivity, and sustainability of supply chain operations by reducing waste, energy consumption, emissions, and costs (Christopher et al. 2004; Sheffi et al. 2005).
- *Industry 4.0 and 5.0*: The concepts that describe the current and future trends of industrial transformation driven by advanced technologies. Industry 4.0 refers to the fourth industrial revolution that is characterized by the convergence of cyber-physical systems that can communicate and cooperate through IoT and AI. Industry 5.0 refers to the fifth industrial revolution that is characterized by the collaboration of humans and machines that can enhance the creativity, innovation, and personalization of products and services.
- *Digitalisation*: The process of using digital technologies to create new or modify existing business processes, models, capabilities, and value propositions. Digitalization can enable more transparent, connected, and intelligent supply chains that can deliver better customer experiences and outcomes. Digitalization can also facilitate the adoption of green supply chain management (GSCM) practices that aim to reduce the environmental impacts of supply chain activities.

The main theme of this book is to explore how these advanced technologies can help SCM to manage disruptive supply chains and achieve resilience in the post-Covid era. The book's objectives are to:

- Review the current state of the art and practice of SCM about these advanced technologies,

- Identify the benefits, challenges, opportunities, and best practices of applying these advanced technologies in SCM,
- Provide empirical evidence and case studies from various industries and contexts on how these advanced technologies can improve SCM performance and resilience, and
- Offer practical recommendations and guidelines for SCM practitioners, policymakers, and stakeholders on how to implement these advanced technologies effectively and efficiently.

The book's scope covers five global manufacturing sectors: automotive, electronics, food & beverages, apparel, and pharmaceutical. These sectors are selected because they represent different characteristics and challenges of SCM in terms of product complexity, demand variability, supply uncertainty, regulatory compliance, environmental impact, etc. The book also covers different aspects and functions of SCM such as procurement, production, distribution, inventory, and logistics.

The book is organized into eleven chapters as follows:

This chapter: Introduction—This chapter provides an overview of the book's main theme, objectives, scope, methodology, and chapter summaries.

Chapter 2: Smart Manufacturing: A Review Toward the Improvement of Supply Chain Efficiency, Productivity, and Sustainability—This chapter reviews how smart manufacturing systems can revolutionize SCM by monitoring and tracking production processes in real-time, providing valuable data that improve and optimize operations and reduce downtime, waste, and energy usage.

Chapter 3: Revolutionizing Supply Chain Management: A Bibliometric Analysis—This chapter uses a bibliometric analysis tool to identify key authors and publications in the field of SCM and advanced technologies, and to detect patterns and trends in the literature.

Chapter 4: Supply chain resilience: A literature review and gap analysis—This chapter conducts a systematic literature review to examine the definitions, features, types, measures, theories, relationships, and effects of supply chain resilience strategies on SCM performance. It also identifies the research gaps and limitations in this field.

Chapter 5: Principal Lessons Learned from COVID-19: Prescriptive and Long-lasting Strategies for Sustainable Supply Chain Improvement—This chapter examines the lessons learned from the pandemic and proposes a long-lasting approach to address current SCM shortcomings. It suggests several prescriptive recommendations based on advanced technologies to enhance supply chain visibility, forecasting, risk management, traceability, and transparency.

Chapter 6: Impact of Digitalisation in Developing Procurement and Supply Chain Resilience in the Post-Pandemic Era—A Study of the Global Manufacturing Sector—This chapter investigates the impact of digitalization in developing procurement and supply chain resilience in the post-pandemic era within the context of the global manufacturing sector. It uses a qualitative approach based on interviews to gather and analyze data from different industries.

Chapter 7: Obstacles In Disruption and Adoption of Green Supply Chain Management (GSCM) Practices by Manufacturing Industries—This chapter explores the reasons that prevent the industrial sector of Karachi from adopting GSCM practices. It uses a literature review and the opinions of industry managers to identify the main obstacles and challenges.

Chapter 8: Improving Supply Chain Resilience with a Control Tower Approach Beyond Covid-19—This chapter analyzes the different types of supply chain control towers (CTs) and the challenges in implementing them. It presents interviews with four companies to tie the literature review to industry practice and discusses the results and implications.

Chapter 9: Phenomenological Study of Pharmaceutical Supply Chain in Pakistan: Innovative Approaches to Minimize Operational Inefficiencies—This chapter conducts a phenomenological study of the pharmaceutical supply chain in Pakistan, and identifies the innovative approaches to minimize operational inefficiencies. It uses an exploratory design and an in-depth interview method to collect and interpret data.

Chapter 10: Supply Chain Resilience during Pandemic Disruption: Evidence from the Healthcare Sector of Pakistan—This chapter investigates the impact of supply chain resilience in the healthcare supply chain of Pakistan when experiencing the COVID-19 pandemic disruption. It uses a qualitative approach based on interviews to collect and analyze data. It also identifies the key strategies of supply chain resilience in COVID-19 disruption.

Chapter 11: The readers of this chapter can expect to learn about, (i) the main contributions and implications of this book for SCM theory and practice, especially in the context of Covid-19 and its aftermath, (ii) the main limitations and challenges of using advanced technologies in SCM, such as standardization, interoperability, compatibility, skills, trust, security, privacy, ethics, regulation, governance, compliance, awareness, readiness, and willingness, (iii) the main directions and opportunities for future research on the relationship between advanced technologies and SCM, such as frameworks, models, standards, protocols, barriers, drivers, integration, adaptation, evaluation, and selection, and (iv) a conceptual model that illustrates the complex and dynamic relationship between advanced technologies and various aspects of SCM, such as integration, interoperability, compatibility, skills, roles, responsibilities, behaviors, ethical, legal, social, and environmental issues, effectiveness, efficiency, and return on investment.

1.2 Background

Supply chain management (SCM) has a long and rich history that can be traced back to the pre-industrial era when local and regional trade networks were established to exchange goods and services. However, the evolution and development of SCM as a distinct field of study and practice began in the twentieth century when several factors such as industrialization, globalization, technological innovation, and

market competition influenced the way supply chains were organized and operated. In general, SCM has gone through four main stages of evolution since the 1960s (Lambert et al. 1998):

Stage 1: Functional integration. This stage involved the consolidation of separate logistics functions such as procurement, production, distribution, inventory, and transportation into two main categories: materials management and physical distribution. The main objective was to reduce costs and improve efficiency by coordinating the flow of materials and products within the organization.

Stage 2: Internal integration. This stage involved the integration of logistics functions with other business functions such as marketing, finance, and operations. The main objective was to align the supply chain strategy with the corporate strategy and to create value for customers by meeting their needs and expectations.

Stage 3: External integration. This stage involved the integration of the organization's supply chain with its external partners such as suppliers, customers, intermediaries, and service providers. The main objective was to enhance collaboration, information sharing, and trust among supply chain partners and to achieve a competitive advantage by leveraging their core competencies and resources.

Stage 4: Network integration. This stage involved the integration of multiple supply chains into a network of interconnected and interdependent entities that can respond to dynamic and uncertain market conditions. The main objective was to achieve agility, resilience, and sustainability by adopting advanced technologies that can enable real-time visibility, communication, coordination, and optimization across the supply chain network.

However, despite the progress made in SCM over the years, there are still many challenges and opportunities that need to be addressed in the face of global disruptions. Disruptions refer to unexpected events or situations that can negatively affect the normal functioning and performance of supply chains. Examples of disruptions include natural disasters, pandemics, wars, terrorism, strikes, cyberattacks, trade wars, etc. Disruptions can cause various impacts on supply chains such as delays, shortages, quality issues, cost increases, demand changes, customer dissatisfaction, etc.

To cope with disruptions, SCM needs to adopt two complementary capabilities: resilience and innovation. Resilience refers to the ability of a supply chain to recover from disruptions and maintain or restore its functionality and performance. Innovation refers to the ability of a supply chain to create or adopt new solutions that can improve its functionality and performance or prevent or mitigate disruptions. Several studies have explored the concepts and practices of supply chain resilience and innovation from different perspectives and contexts. For example:

- Christopher et al. (2004) proposed a framework for building agile supply chains that can cope with volatile demand by using strategies such as postponement, mass customization, and collaborative relationships.
- Sheffi et al. (2005) identified four types of resilience strategies: redundancy, flexibility, security, and collaboration, and discussed how they can be applied in different scenarios.
- Hohenstein et al. (2015) conducted a systematic literature review on supply chain risk management and proposed a classification scheme based on four dimensions: sources, outcomes, mitigation strategies, and performance effects of supply chain risks.
- Wieland et al. (2017) developed a conceptual model of supply chain innovation and suggested that it can be driven by three factors: opportunity recognition, knowledge access, and mobilization.
- Ivanov et al. (2020) examined the impact of the COVID-19 pandemic on global supply chains and proposed a framework for structural dynamics analysis and control to assess and mitigate the ripple effects of disruptions.

However, there are still some research gaps and limitations that this book aims to address. Some of them are:

- The lack of comprehensive and holistic approaches that can integrate different aspects and functions of SCM with advanced technologies to create value and competitive advantage.
- The lack of empirical evidence and case studies on how advanced technologies can enhance supply chain resilience and innovation in different industries and contexts.
- The lack of practical recommendations and guidelines for SCM practitioners, policymakers, and stakeholders on how to implement advanced technologies effectively and efficiently in their supply chains.

Therefore, this book intends to fill these gaps by providing a state-of-the-art review and analysis of advanced technologies for the management of disruptive supply chains and achieving resilience in the post-Covid era.

1.3 Methodology

In our call for contributions to this volume on "**Advanced Technologies for the Management of Disruptive Supply Chains: Achieving Resilience in Supply Chains for Post-Covid Era**," we went through various email lists of professional associations. Personal invitations were also sent to target researchers and scholars as well. We received a total of fifteen "two-page" long abstracts as the expression of interests. Based on the initial screening by our review panel, the authors of thirteen chapters were invited to submit the complete chapters. We received twelve chapters from the contributors that went through a double-blind review process. The reports

from the independent reviewers were sent to the authors to address the issues and incorporate the suggestions made by the reviewers. Only nine chapters made it to the final stage of acceptance. The final versions of these nine chapters have been edited and included in this volume.

1.4 Research Categories

The chapters thus compiled are classified into five categories following the structure of the book. The first category, the current one, "*An Overview of Advanced Technologies for the Management of Disruptive Supply Chains*," presents the introduction and preview of this book. The second category examines the Theoretical Models for Building Resilient Supply Chains. Four state-of-the-art chapters on this theme include (i) *Smart Manufacturing: A Review Toward the Improvement of Supply Chain Efficiency, Productivity, and Sustainability*, (ii) *Revolutionizing Supply Chain Management: A Bibliometric Analysis of Industry 4.0 and 5.0*, (iii) *Supply Chain Resilience: A Literature Review and gap analysis*, and (iv) *Principal Lessons Learned from COVID-19: Prescriptive and Long-lasting Strategies for Sustainable Supply Chain Improvement*. The third category showcases five unique contributions demonstrating the use of advanced technologies in building sustainable supply chains: (i) *Impact of Digitalisation in developing Procurement and Supply Chain Resilience in the Post-Pandemic Era—A study of the Global Manufacturing Secto*r, (ii) *Obstacles in Disruption and Adoption of Green Supply Chain Management (GSCM) Practices by Manufacturing Industries*, (iii) *Improving Supply Chain Resilience with a Control Tower Approach Beyond Covid-19*, (iv) *Phenomenological Study of Pharmaceutical Supply Chain in Pakistan: Innovative Approaches to Minimize Operational Inefficiencies***,** and **(v)** *Supply Chain Resilience during Pandemic Disruption: Evidence from the Healthcare Sector of Pakista*n.

The final category, Conclusions, and Future Research Directions, overviews the key insights and learning points as well as the future research avenues contained in this book.

1.5 Conclusion

This book has explored the topic of advanced technologies for the management of disruptive supply chains and achieving resilience in the post-Covid era. The book has provided a comprehensive and holistic review and analysis of the current state of the art and practice of SCM and advanced technologies, as well as empirical evidence and case studies from various industries and contexts. The book has also offered practical recommendations and guidelines for SCM practitioners, policymakers, and stakeholders on how to implement advanced technologies effectively and efficiently to build resilience in their supply chains.

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Part II
Theoretical Models for Building Resilient Supply Chains

Chapter 2
Smart Manufacturing: A Review Toward the Improvement of Supply Chain Efficiency, Productivity, and Sustainability

Mohammad Abul Kashem, Mohammad Shamsuddoha, and Tasnuba Nasir

Abstract Smart manufacturing is an innovative approach to creating a more agile supply chain process capable of adapting to changing market demands and conditions to improve efficiency, productivity, and sustainability. These technologies successfully optimize their factories to decrease material waste, save money on equipment, supplies, and upkeep, and boost supply chain performance. Owing to these facts, this study reviewed how smart manufacturing systems make a revolution by monitoring and tracking production processes in real-time, providing manufacturers with valuable data that improved and optimized operations and reduced downtime, waste, and energy usage. This study aims to examine the existing research on the effects of smart manufacturing on developing the supply chain and to pinpoint the significant developments, problems, and possibilities in these fields. This systematic review covered how these areas' latest research and developments relinquish manual operations and embrace automation and smart technologies for supply chain transformation. The study included a comprehensive search of relevant databases following the PRISMA guidelines for reporting systematic reviews. The review critically investigated data management, privacy, security problems, and the possibilities and obstacles related to deploying these technologies in the real world. In advance, this study reappraised that smart manufacturing allows manufacturers to manage their supply chains better, reducing the time and resources required to coordinate and manage suppliers, logistics, and inventory. At long last, these reviewed data and insights will aid decision-making to reduce waste, improve productivity, and increase overall profitability in the supply chain literature.

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Keywords Smart manufacturing · Supply chain · Efficiency · Productivity · Sustainability · Post-Covid · PRISMA

2.1 Introduction

Smart manufacturing is a rapidly evolving field that has the potential to transform the manufacturing industry by increasing efficiency, improving product quality, and reducing costs. Additionally, these organized efforts ensure a productive manufacturing environment for an effective, adaptable, and sensible supply chain (Dey et al. 2021). Likewise, supply chain mechanism enables organizations to rapidly adapt to vicissitudes in the market, consumer preferences, and emerging trends (Jawahar et al. 2020). In addition, this amalgamation ensures reducing lead times (Correia et al. 2021), increasing production speed (Chen et al. 2020), and improving delivery times, including closing ties with suppliers, customers, and partners to ensure the supply chain efficiency and effectiveness by identifying and addressing potential bottlenecks (Lin et al. 2016). So, this process comprises a combination of strategies, technologies and techniques that allow companies to respond to changes in demand and supply quickly, even in supply chain disruptions.

In addition, smart manufacturing enhances manufacturing operations (Kalsoom et al. 2020) via cutting-edge technology like artificial intelligence (AI), the Internet of Things (IoT), and machine learning (ML) with efficiency (Felstead 2019). Using advanced technologies, manufacturing systems gather and analyze vast amounts of data on production processes, equipment performance, and product quality (Ambrogio et al. 2022). With a comprehensive approach to data collection, these systems monitor every facet of the production process, from the raw materials used to the finished products produced (Alkhader et al. 2021), ultimately leading to greater profitability for manufacturers (Khan et al. 2022), even for innovation (Lin et al. 2016). As a result, these systems proactively identify potential issues and anomalies in real-time, even before they arise, as Wu et al. (2023) highlighted. As technology continues to evolve, smart manufacturing will likely become even more advanced, offering new opportunities for innovation and growth in the manufacturing sector.

Smart manufacturing enables closed-loop recycling systems, where materials are recycled and reused within the same production process (Sadeghi et al. 2022). This would reduce the need for new raw materials and minimize waste (Chien et al. 2022) while reducing the manufacturing carbon footprint (Nazir et al. 2021). To further ensure supply chain sustainability, smart manufacturing enables transparency and traceability throughout the supply chain (Kalsoom et al. 2020; Wu and Zhang 2022). This would allow consumers to track products' origin and production process, ensuring that they are ethically sourced and manufactured (Dutta et al. 2020). However, smart manufacturing transformed by producing customized products on a large scale (Adel 2022b), catering to individual customer preferences and needs by optimizing production processes and reducing energy consumption (Versino et al.

2023) despite the implementation challenges (Terry et al. 2020). Smart manufacturing technology could help ensure supply chain sustainability by reducing waste, optimizing resource usage, and enabling transparency and traceability throughout the supply chain.

2.2 Smart Manufacturing and Agile and Flexible Supply Chain Process

During the COVID-19 pandemic, smart manufacturing technologies enabled many manufacturers to quickly pivot their supply chain operations to produce essential medical equipment and supplies (Diaz-Elsayed et al. 2020). As a result, the company responded rapidly to changes in customer demand and reduced lead times significantly (Nazir et al. 2021). For instance, IBM improved its supply chain operations by implementing smart manufacturing technologies (Oh and Jeong 2019). The company used IoT sensors to monitor the temperature and humidity of its products during shipping, reducing the risk of spoilage (Wu et al. 2023). In contrast, AI algorithms optimize logistics operations, reducing transportation costs and improving delivery times (Shamsuddoha et al. 2023; Nath 2021). Using AI algorithms, manufacturers identify potential supply chain disruptions and plan for alternative routes or suppliers to lessen the effects of supply chain interruptions and keep business continuity. Hence, more manufacturers are embracing smart manufacturing technologies to create a more responsive and flexible supply chain.

By using these technologies, manufacturers create a more responsive and agile supply chain that quickly adapts to changes in demand or supply. For example, IoT sensors track the operation of manufacturing machinery in real-time (Tuffnell et al. 2019). This data be analyzed to identify potential issues before they cause downtime (Sadeghi et al. 2022). Similarly, machine learning (ML) algorithms optimize production schedules based on machine capacity, material availability, and customer demand (Touckia et al. 2022). Smart manufacturing faces certain limitations in terms of its flexible supply chain despite its involvement in the industry. One of the major shortcomings is the absence of a comprehensive framework that integrates all the manufacturing technologies and systems. Though various individual technologies and systems have been developed, manufacturers still require a cohesive framework that can assist them in making informed decisions regarding which technologies to implement and how to integrate them effectively. Moreover, smart manufacturing requires improved data analytics and management tools. With the exponential growth of data generated by smart manufacturing systems, there is a pressing need for advanced data analytics tools that can help manufacturers comprehend this data and utilize it to optimize their operations. Additionally, superior data management tools are essential to ensure data reliability, accuracy and security.

Table 2.1 shows that smart manufacturing uses advanced technologies like the IoT, AI and ML to automate and optimize manufacturing processes with greater

Table 2.1 Smart manufacturing system and operations optimization

Smart manufacturing systems	How they make revolution
Real-time monitoring and tracking (Bourke 2019; Tuffnell et al. 2019)	Smart manufacturing systems gather data from different production phases in an instantaneous fashion using cutting-edge sensors and tracking tools. They then use AI and ML algorithms to spot trends, anticipate problems, and improve processes
Predictive maintenance (Adel 2019; Sadeghi et al. 2022; Sun et al. 2022)	Smart manufacturing systems use real-time equipment and machinery monitoring to predict maintenance requirements and schedule necessary maintenance tasks. This proactive approach helps to minimize unexpected downtime, extend equipment lifespan, and prevent costly repairs
Quality control (Terry et al. 2020; Zhang et al. 2021)	Real-time monitoring allows for the immediate detection of quality issues, allowing for corrections to be made before the production process is completed
Resource optimization (Jha and Siano 2021; Pu et al. 2020)	For optimization of resource consumption, such as consumption of energy, water and raw material, smart manufacturing utilizes monitoring and tracking resource usage in real-time
Visibility (Lin et al. 2016; Liu et al. 2022)	Intelligent manufacturing systems enable real-time tracking, which facilitates inventory level optimization, minimizes wait times, and enhances the overall effectiveness of the supply chain
Enhanced flexibility (Dey et al. 2021; Nazir et al. 2021)	Smart manufacturing systems quickly adapted to demand or production requirements changes for more agile production processes and excellent responsiveness to customer needs
Automation (Bellavista et al. 2021; Kang et al. 2016; Nguyen et al. 2021)	Automation, a core component of smart manufacturing, improves efficiency and consistency in manufacturing processes, reducing lead times and increasing production speed and greater flexibility in production to adjust to changes in demand
Data analytics (Bourke 2019; Chung et al. 2018; Touckia et al. 2022)	Smart manufacturing generates vast amounts of data that be analyzed to identify patterns and trends to optimize production processes, identify inefficiencies, and improve the supply chain by reducing costs and increasing efficiency

(continued)

Table 2.1 (continued)

Smart manufacturing systems	How they make revolution
Collaborative robotics (Adel 2022b; Butdee et al. 2022; Sun et al. 2022)	Collaborative robots or cobots work alongside humans for repetitive or dangerous tasks with a quickly reprogrammable option
Digital twins (Frankó et al. 2020; Nguyen et al. 2021)	Digital twins are digital representations of physical assets, such as machines or production lines to simulate production processes to reduce downtime and improve efficiency

efficiency, flexibility, and agility in manufacturing operations and flexible supply chain process (Terry et al. 2020). However, in today's fast-paced and competitive manufacturing industry, data-driven decision-making is crucial to optimizing manufacturing operations (Liu et al. 2022). By providing manufacturers with valuable data, it is possible to make informed decisions about production schedules, inventory management, equipment maintenance, and quality control (Dzhuguryan and Deja 2021; Versino et al. 2023; Vieira 2016) and identify the root causes of defects and implement corrective actions (Jawahar et al. 2020). For instance, relevant data on inventory levels, demand forecasts, and lead times are used to optimize inventory management, such as inventory levels and demand, adjust production schedules, and reduce inventory carrying costs (Brooks et al. 2021). So, as the manufacturing industry continues to become more data-driven, the ability to analyze and use data becomes a critical factor for supply chain success.

2.3 Smart Technologies and Supply Chain Transformation

By embracing smart manufacturing, manufacturers possibly create a more competitive supply chain (Pu et al. 2020) and meet the demands of an ever-changing market with improved efficiency (Jha et al. 2022), reduced costs (Lei et al. 2022), and increased production speed (Alkhader et al. 2021; Bajracharya et al. 2020; Dzhuguryan and Deja 2021; Nazir et al. 2021; Wu and Zhang 2022). So, cost-saving strategies support organizations save money on equipment, supplies, and upkeep while ensuring a smooth supply chain. Leasing equipment, optimizing inventory management, purchasing in bulk, and conducting regular maintenance (Dutta et al. 2020) are just a few strategies that reduce costs and boost supply chain performance.

From Table 2.2, these ingenious technologies serve companies to boost productivity, cut expenses, and enhance overall performance by converting manual supply chain processes to automated ones. Assumably, there is a need for research into the social and environmental impacts of smart manufacturing. While the benefits of smart manufacturing are clear, there is a need to understand the potential negative effects on workers, communities, and the environment. Efficiency, productivity,

Table 2.2 Smart technologies for supply chain transformation from manual operations to embracing automation

Smart technologies	Description	Benefits of smart manufacturing
Internet of Things (IoT) (Belhi et al. 2022; Felstead 2019; Jha et al. 2022; Kamiebisu et al. 2022; Sylim et al. 2018)	Sensors and devices that collect data and communicate with each other over the internet	Real-time tracking of inventory, improved visibility into supply chain processes, reduced manual labor
Artificial Intelligence (AI) (Felstead 2019; Oh et al. 2019; Sun 2021; Terry et al. 2020)	Advanced algorithms that analyze data, predict outcomes and make decisions	Better demand forecasting, improved supply chain planning and optimization, enhanced decision-making
Robotic process automation (RPA) (Adel 2022b; Morris and Thomas 2020)	Software robots that automate repetitive tasks and processes	Increased efficiency and accuracy, reduced labor costs, improved data quality
Blockchain (Kashem et al. 2023; Khan et al. 2022)	A decentralized ledger that provides a secure and transparent way to track and verify transactions	Improved supply chain traceability, enhanced transparency and accountability, reduced risk of fraud
Cloud computing (Chung et al. 2018; Jha and Siano 2021; Pu et al. 2020)	A system of distant computers that processes, stores, and manages data	Improved scalability and flexibility, reduced IT costs, increased collaboration and accessibility
3D printing (Diaz-Elsayed et al. 2020)	Additive manufacturing technology that creates physical objects from digital designs	Reduced lead times, increased customization and flexibility, improved supply chain resilience
Augmented reality (AR) (Sadeghi et al. 2022)	Technology that overlays digital information onto the physical world	Improved training and on boarding, enhanced visualization and communication, increased efficiency and accuracy

sustainability, and social responsibility are key attributes of smart manufacturing that can be achieved by addressing these research gaps.

2.4 Methodology

The researchers conducted an open and reproducible systematic review using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) under the paradigm of narrative review. The earlier research idealized the guidelines (Kashem et al. 2022). Admittedly, the initial development of the research question pre-set the scope of the research: "*How does smart manufacturing impact supply*

chain efficiency, productivity, and sustainability?" By using a systematic approach, searches for relevant studies that address the research question. In this case, the search would be conducted on Google Scholar and PubMed with specific search terms related to smart manufacturing, such as the technologies involved, the benefits, challenges, or implementation strategies. However, the keywords used related to smart manufacturing databases were as "smart manufacturing", "supply chain", " supply chain management", and so on. Also, the inclusion and exclusion criteria (in Table 2.3) have ensured that only relevant studies are included in the analysis.

When conducting a systematic review using the PRISMA framework, it is crucial to identify the prevailing ideologies that underpin the process. These ideologies typically include the need to develop a well-defined protocol, conduct a thorough search for relevant studies, carefully screen search results, extract relevant data, evaluate the included studies' quality, synthesize the analysis results, and interpret and report the findings clearly and concisely. The study organizes and summarizes these critical steps in the PRISMA analysis using a standardized format in Fig. 2.1, such as the one presented in Tables 2.4 and 2.5.

Figure 2.1 depicts the systematic review procedures, while Table 2.5 summarizes the findings. Studies identified through the initial search are categorized according to their relevance to the research question during the screening process. The literature review involves two stages, each of which is crucial in ensuring that only the most relevant and high-quality studies are included in the analysis. Researchers screen the titles and abstracts of potentially relevant studies and thoroughly examine the full text to determine confidently whether each study meets the rigorous inclusion criteria. In the extended format, studies are screened based on their title, abstract, and full text to ensure the analysis results are robust and meaningful. We excluded irrelevant studies and selected those that meet inclusion criteria, such as being published in a peer-reviewed journal and focusing on smart manufacturing databases. Once the relevant studies have been identified, information on the study design, methodology, results, and conclusions are reviewed. The careful and transparent reporting of the key findings and their implications in light of the relevant studies is critical to any meaningful discussion. It allows for a better understanding of the results and promotes transparency and credibility in the research process. In the end, performing

Table 2.3 Inclusive and exclusion criteria

Inclusive criteria	Exclusive criteria
• The study must be published in English • The study must be a peer-reviewed journal article or conference proceeding • The study must be related to smart manufacturing and supply chain • Papers that discuss quantitative or qualitative research • Papers that present empirical findings, case studies, or theoretical perspectives	• Studies that are not related to smart manufacturing or supply chain management • Research that does not explicitly discuss the impact of smart manufacturing on the supply chain • Research that is outdated, unpublished, or not peer-reviewed • Studies that are not available in English or not accessible through academic databases

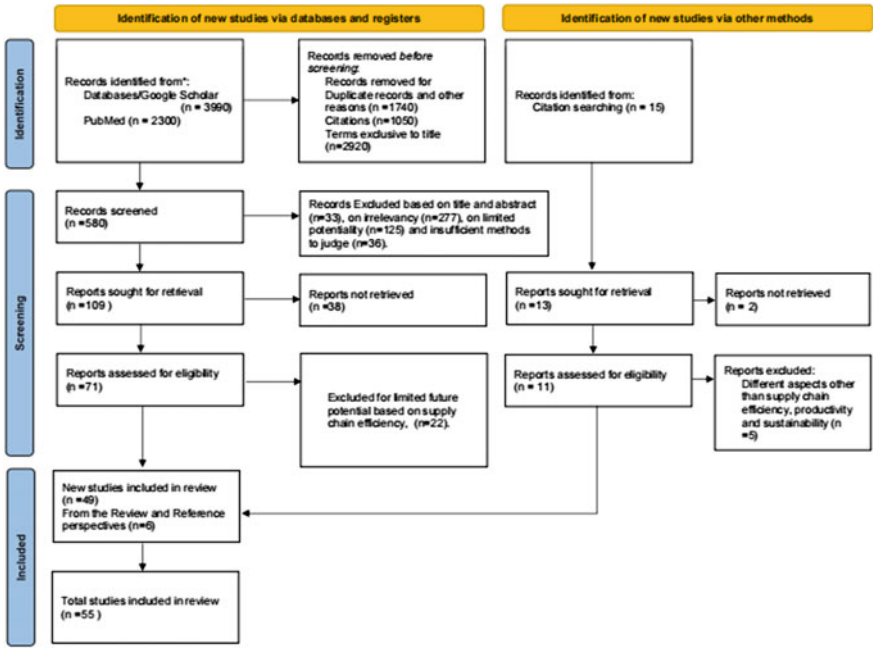

Fig. 2.1 PRISMA flowchart

Table 2.4 Systematic literature search and bases of inclusion and exclusion

Keywords/search string	Search engine	No. of papers
"smart manufacturing"	Google Scholar	3990
"smart manufacturing" and "supply chain"	Google Scholar	46
"smart manufacturing"	PubMed	2300
"smart manufacturing" and "supply chain"	PubMed	50

a PRISMA study on smart production over the supply chain gave a thorough summary of the entire research and revealed knowledge gaps that might call for more research.

2.5 Common Strategies for Supply Chain Efficiency, Productivity, and Sustainability

Smart manufacturing integrated advanced technologies such as AI, IoT, and cloud computing into manufacturing processes to improve operations, enhance productivity, and reduce their environmental impact by automating tasks and streamlining processes (Adel 2022a). By using robotics and AI, manufacturers automate tasks such

Table 2.5 Summary report on PRISMA flowchart

Introduction	This PRISMA flowchart provides a comprehensive guide to the steps involved in conducting a systematic review and ensures transparency and reproducibility. Numerous studies have been done in supply chain management and smart production over the years. This report analyzed the year-wise research trends in the abovementioned fields using the PRISMA flowchart
Search string and criteria	To conduct this study, we searched several electronic databases, including PubMed and Google Scholar. The search terms used were "supply chain," "smart manufacturing," and "smart manufacturing and supply chain." We limited our search to articles published between 2014 and 2023. After screening the titles and abstracts, we selected articles that met our inclusion criteria
Summary trend	After screening the articles, we identified 55 studies that met our inclusion criteria. We then analyzed the year-wise research trends using the PRISMA flowchart. The results are presented below **2014–2016: 04** The focus of these studies shifted towards using advanced technologies such as RFID, IoT, and big data analytics from 5 studies **2017–2020: 19** These studies during this period focused on various aspects of supply chain, including sustainability, resilience, agility, and customer satisfaction, inclusive to machine learning and artificial intelligence **2021–2023: 32** Although the number of studies during this period was relatively low, these studies focused on emerging technologies such as blockchain, digital twins, and Industry 4.0
Overview	The year-wise research trend analysis using the PRISMA flowchart unwrapped that the number of studies on smart manufacturing and supply chain has been increasing steadily. The focus of these studies has also been shifting from traditional metrics to advanced technologies and emerging trends. In recent years, there has been an increase in the use of ML, AI, IoT, and big data analytics, showing a rising interest in using these technologies to improve performance

as assembly, quality control, and material handling, reducing the need for manual labor and increasing production output (Kalsoom et al. 2020). Furthermore, smart manufacturing technologies enable manufacturers to optimize their supply chains, reducing lead times and improving responsiveness to customer demand (Oh and Jeong 2019). Finally, intending to enhance the sustainability of manufacturing operations, optimized production processes reduce waste and energy consumption, leading to a smaller environmental footprint (Vieira 2016). Additionally, these manufacturing technologies allow for the use of clean energy sources, the reduction of greenhouse gas pollution, the use of more environmentally friendly materials, and the optimization of transit paths (Correia et al. 2021). As such, smart manufacturing will play an increasingly critical role in the future of manufacturing, enabling manufacturers to meet the demands of the modern marketplace and reduce their environmental impact.

2.5.1 Smart Manufacturing and Supply Chain Efficiency

Smart manufacturing has revolutionized supply chain operations by improving efficiency through real-time monitoring and analysis of supply chain data (Lin et al. 2016). According to a recent study, smart manufacturing enhances supply chain efficiency, saves costs and improves customer satisfaction (Khan et al. 2022). IoT sensors and other smart technologies enable manufacturers to monitor the status of their production processes, identify bottlenecks, and make real-time decisions to optimize their operations (Sun et al. 2022). This leads to reduced lead times, increased throughput, and enhanced agility (Dutta et al. 2020). In addition, smart technologies such as IoT sensors and RFID tags are used to track products (Wu et al. 2023). So, this real-time visibility helps companies optimize their supply chain operations, reducing lead times and improving delivery performance which might be embodied in Table 2.6.

2.5.2 Smart Manufacturing and Supply Chain Productivity

Smart manufacturing also improves productivity by optimizing manufacturing processes and reducing waste. Smart technologies such as AI and big data analytics are used to analyze manufacturing data and identify areas where improvements can be made (Kalsoom et al. 2020). By using data to optimize manufacturing processes, companies increase throughput, reduce cycle times, and improve product quality (Sadeghi et al. 2022). For example, if a machine is experiencing a problem, smart manufacturing systems alert operators, enabling them to take corrective action immediately (Touckia et al. 2022). This reduces downtime and ensures that production runs smoothly (Dzhuguryan and Deja 2021). So, with the increasing global competition and customers' demand for faster delivery, better quality, and eco-friendliness, organizations need to continuously improve their supply chain performance (in Table 2.7).

2.5.3 Smart Manufacturing and Supply Chain Sustainability

Supply chain sustainability might work out for the ability of organizations to minimize their environmental impact while maintaining profitability.

As per Table 2.8, supply chains must be made more efficient, productive, and sustainable for companies to stay competitive and satisfy changing customer demands. Businesses might streamline their production processes, reduce waste, and boost product quality by utilizing clever technologies like IoT, AI, and big data analytics. Furthermore, smart manufacturing usually tracked their energy usage,

Table 2.6 Strategies for supply chain efficiency concerning smart manufacturing

Strategy	Details
Lean manufacturing (Jawahar et al. 2020)	Eliminating waste, cutting lead times, and enhancing the flow of materials and information throughout the supply chain are all made possible by lean production concepts
Technology integration (Frankó et al. 2020; Nath and Sarkar 2020)	Utilizing software for business resource planning (ERP), warehouse management systems, and transportation management systems helps to optimize inventory levels, streamline operations, and enhance collaboration throughout the supply chain
Demand forecasting (Chien et al. 2022; Kamiebisu et al. 2022)	Accurately forecasting demand endorses reducing inventory levels, minimizing stock-outs, and improving production scheduling
Supplier collaboration (Liu et al. 2022)	Collaborating with suppliers patronized to improve supplier performance, reduce lead times, and improve quality
Inventory management (Burmester et al. 2017; Dey et al. 2021; Kang et al. 2016)	Consolidating orders to lower the number of trips necessary to transport goods reduces numerous shipments and improves route effectiveness
Network design optimization (Cai 2014; Chung et al. 2018)	Evaluate the supply chain network design to ensure efficient routes between suppliers, manufacturers, distribution centers, and customers by considering the distance, transportation modes, and delivery frequency
Last-mile delivery optimization (Correia et al. 2021)	Focusing on optimizing the final leg of delivery to customers, alternative delivery methods such as crowdsourcing, lockers, or drones and exploring local distribution centers to reduce delivery times and transportation costs
Data analysis (Versino et al. 2023)	Use data analysis to identify trends and opportunities for route optimization through the factors such as order volume, delivery frequency, and transportation costs to identify areas for improvement
Packaging optimization (Sadeghi et al. 2022)	Evaluate packaging to ensure efficiency and maximize available space by reducing the number of shipments required and optimizing route efficiency

(continued)

Table 2.6 (continued)

Strategy	Details
Routing software (Adel et al. 2022)	Utilize routing software to create optimal delivery routes based on factors such as traffic, weather, and driver availability by integrating real-time GPS data to make route adjustments as needed
Ensure transparency and accountability (Alkhader et al. 2021)	Establishing open communication channels and responsibility between all participants in the supply chain ensures that everyone is working toward the same objectives and that any issues are promptly identified and resolved
Continuously monitor and improvement (Terry et al. 2020)	Regularly review KPIs and metrics, and use this data to make informed decisions about process improvements, supplier relationships, and other areas of the supply chain that need attention

reduced carbon emissions, and lowers their environmental footprint. Smart manufacturing will play an increasingly important role in driving innovation and growth as the manufacturing industry evolves.

2.6 Criticism of Emerging Technologies Issues Related to Data Management, Privacy, and Security

Emerging technologies are increasingly used in manufacturing to optimize production processes and increase efficiency. However, as with any new technology, there are concerns about its impact on data management, privacy, and security as for emerging technologies in smart manufacturing (Alkhader et al. 2021; Ambrogio et al. 2022), which are:

- *Data security breaches*: Vulnerable to data security breaches supposed to compromise sensitive data and potentially lead to significant financial or reputational damage for organizations.
- *Lack of standards*: Due to no standardized protocols or best practices for managing data in smart manufacturing systems leading to inconsistencies and errors in data management.
- *Privacy concerns*: Handling vast amounts of data about employees, customers, and products might concern the privacy and security of this data.
- *Data ownership*: Disputes and legal challenges might arise due to the ambiguity surrounding data ownership generated by smart manufacturing systems.
- *Data quality issues*: Issues with data quality, such as inconsistencies, errors, or incomplete data to function effectively.

Table 2.7 Strategies for supply chain efficiency in smart manufacturing

Strategy	Details
Automation (Bellavista et al. 2021; Kang et al. 2016; Nguyen et al. 2021)	Automating repetitive tasks such as order processing, invoicing, and inventory management reduces staff time for more value-added activities, resulting in increased productivity
Cross-functional training (Jha et al. 2022)	Providing cross-functional training to employees improves collaboration across different departments and increases efficiency
Performance metrics (Lin et al. 2016)	Setting and monitoring performance metrics favors identifying inefficiencies and areas for improvement, resulting in increased productivity
Outsourcing (Morris and Thomas 2020)	Outsourcing non-core tasks like warehouse management, logistics, and transportation boosts output by enabling businesses to concentrate on their core skills
Increasing inventory levels of raw materials (Dey et al. 2021)	Safety stock, economic order quantity (EOQ), lead time reduction, just-in-time (JIT), vendor-managed inventory (VMI), strategic sourcing and capacity expansion are prevalent ways to consider in this aspect
A top-down approach to leadership (Dzhuguryan and Deja 2021)	For leaders to be effective in supply chain productivity, engaging in various activities such as efficient communication, establishing procedural standards, prioritizing tasks, enabling the workforce, and a robust training program is worth functioning
Paying close attention to the workforce and empowerment (Ambrogio et al. 2022)	Regular check-ins, active listening, recognition and rewards boost employees' motivation and engagement and encourage them to continue performing at a high level
Big data approach in manufacturing (Nguyen et al. 2021)	It entails gathering sizable quantities of data from many areas, including sensors, machines, production systems, and other pertinent sources to better industrial processes through predictive maintenance, real-time tracking, and other methods

- *Integration challenges*: Integration with various technologies and systems might create data management, privacy, and security challenges.
- *Lack of transparency*: Due to complexity and opaque might be difficult for stakeholders to understand how data is being collected, managed, and used.
- *Regulatory compliance*: Need to comply with a range of different regulations related to data management, privacy, and security, which be challenging for organizations to navigate.

Table 2.8 Smart manufacturing and supply chain sustainability

Strategy	Particulars
Green logistics (Sun et al. 2022)	Utilizing environmentally friendly transportation modes such as rail and sea freight degrades emissions and lower costs
Sustainable packaging (Versino et al. 2023)	Using sustainable packaging materials such as biodegradable plastics and recycled paper reduces waste and improves sustainability
Energy efficiency (Frankó et al. 2020)	Energy-efficient practices include using renewable energy sources, optimizing lighting and heating, and reducing energy consumption during production revamp sustainability
Social responsibility (Liu et al. 2020)	Ensuring that suppliers meet ethical and social responsibility standards meliorates sustainability and reputation
Implement environmental management systems (Jha et al. 2022)	It helps businesses identify, manage, monitor, and improve their environmental performance complying with environmental regulations and avoiding the risks of environmental incidents
Promote sustainable transportation (Sun et al. 2022)	Encouraging employees to use public transportation or carpooling is supposed to reduce a business's carbon footprint and even offer incentives to employees who opt for sustainable modes of transportation
Use eco-friendly materials (Jha et al. 2022)	Choosing eco-friendly materials for products or packaging significantly minimizes the environmental impact of a business, whereas using recycled materials and reducing packaging impact to curtail waste and improve a company's overall sustainability
Environmental audit and improvement (Dutta et al. 2020)	An environmental audit helps businesses identify areas where they improve their environmental performance and identify opportunities to reduce waste, energy consumption, and emissions
Implement sustainable practices (Jha et al. 2022)	Sustainable practices such as reducing energy consumption, recycling, renewable energy sources assist businesses in shrinking their environmental impact while saving money in the long run
Engage with stakeholders (Jha and Siano 2021)	This includes customers, suppliers, and investors who help businesses build a culture of sustainability by raising awareness of environmental issues and encouraging stakeholders to take action for a more sustainable future in maintaining profitability
Implement energy conservation measures (Dutta et al. 2020)	This lessening technique includes switching to energy-efficient light bulbs, using renewable energy sources, and using energy-efficient equipment

- *Risk management*: A wide range of data management, privacy, and security risks for effective management to prevent potentially serious consequences.

From the above considerations, several studies have highlighted these concerns and the need for better data management, privacy, and security measures in smart manufacturing. For instance, a study by Dutta et al. (2020) identified privacy and security as the most significant challenges in Industry 4.0, emphasizing the need for more robust data protection measures. Another study by Kashem et al. (2022) proposed a blockchain-based solution for secure data sharing in smart manufacturing, providing a decentralized and tamper-proof system to ensure data privacy and security (Wu and Zhang 2022). Similarly, a study by Chung et al. (2018) proposed a privacy-preserving federated learning framework for collaborative manufacturing, allowing multiple parties to share data while protecting individual privacy. Thus, future research should focus on developing and implementing these measures to ensure emerging technologies' safe and ethical use in smart manufacturing.

2.7 Post-COVID-19 Insights and Lessons

The COVID-19 pandemic has profoundly impacted the manufacturing industry, forcing companies to adapt their practices and processes to ensure the safety of their workers while maintaining productivity (Ambrogio et al. 2022). Initially, smart manufacturing, which relies heavily on automation, robotics, and data analysis, has emerged as a key solution for manufacturers looking to improve efficiency, reduce costs, and meet the demands of an increasingly competitive market (Kalsoom et al. 2020). As companies continue to adapt to the new reality of the post-COVID world, smart manufacturing will play an increasingly important role by accelerating the adoption of smart manufacturing practices and technologies (Diaz-Elsayed et al. 2020). More specifically, the pandemic has accelerated the adoption of smart manufacturing practices as companies look for ways to operate more efficiently with fewer employees on the shop floor (Ambrogio et al. 2022). With social distancing requirements and restrictions on travel and in-person meetings, companies have had to find new ways to communicate and collaborate remotely (Hacker et al. 2020). This has led to an increased focus on automation and digitalization, which are vital components of smart manufacturing (Terry et al. 2020). However, the use of artificial intelligence (AI) and machine learning (ML) in manufacturing has also become more prevalent during the pandemic (Nazir et al. 2021). These technologies are being used to monitor production lines, predict machine failures, and optimize processes, reducing the need for human intervention and improving overall efficiency (Sadeghi and Seo 2022). As a result, companies are able to produce more with fewer workers, reducing their labor costs and improving their bottom line. Hence these are the baseline for the up-gradation with the learning from COVID-19:

Owing to the above facts in Table 2.9, the COVID-19 pandemic has highlighted the importance of smart manufacturing as a means of improving efficiency, reducing

Table 2.9 Key insights and implications of smart manufacturing

Insights	Benefits
Remote work and collaboration (Alkhader et al. 2021)	Smart manufacturing allows for remote monitoring of production lines and machines (Kalsoom et al. 2020), enabling workers to collaborate virtually and reducing the need for in-person interactions (Hacker et al. 2020)
Automation and AI (Nazir et al. 2021)	Companies will continue investing in automation technologies to improve efficiency and reduce costs (Ambrogio et al. 2022), and AI and ML will be increasingly crucial in optimizing processes (Liu et al. 2020)
Cybersecurity (Felstead 2019)	As manufacturers become more reliant on digital technologies, they must invest in robust cyber-security measures to protect against cyber-attacks (Dutta et al. 2020)

costs, and ensuring the safety of workers (Adel 2022b). As companies look to adapt to the new normal, the investment technology-prone-operation efficiency (Dutta et al. 2020), reduced human intervention (Sadeghi et al. 2022) and closer collaboration between manufacturers and technology providers (Oh and Jeong 2019) are going concerned. Thus, the industry must continue to invest in new technologies and collaborate closely with technology providers to drive innovation and stay ahead of the curve.

2.8 Post-Covid Implications

The manufacturing sector has been significantly affected by COVID-19, which has resulted in a severe supply chain shock for the forward and backward sides of the process. Smart technological integration is vital for industries to protect against possible shocks. Integrating smart technologies like the Internet of Things (IoT), artificial intelligence (AI), and automation has allowed this shift. Manufacturers may prioritize productivity, efficiency, and sustainability by implementing smart manufacturing to face upcoming challenges. Manufacturers are now more cautious due to the pandemic's exposure to supply chain vulnerabilities. They get visibility into their supply chains by utilizing IoT devices and real-time data analytics, which enables them to respond proactively to changes in demand and potential interruptions. Automation and AI-driven technologies significantly raise productivity by streamlining processes and eliminating waste. Industry 5.0, where robots collaborate with human workers, boosts productivity and efficiency. Smart manufacturing also provides a road to sustainability in addition to productivity improvements. Manufacturers can utilize AI to optimize energy use, decrease waste, and lower

their carbon footprint in response to consumers' increased environmental consciousness and demand for eco-friendly products. Thus, IoT, AI, and automation technologies are becoming necessary tools for organizations to survive and grow in these epidemic times. Smart manufacturing is advantageous because it delivers sustainability, adaptability, and resilience.

2.9 Conclusion

Organizations operating in rapidly changing environments require an agile, flexible supply chain process. This process enables businesses to respond promptly to shifting dynamics in both supply and demand, decrease waiting periods, enhance customer service, boost efficiency, better manage risks, and gain a competitive advantage. Depending on this systematic review, this dynamism included the integration of Artificial Intelligence (AI) and Machine Learning (ML) that optimize demand forecasting while adopting Robotics and Automation Technologies that improve supply chain efficiency. Again, this smart manufacturing idealized blockchain technology to boost sustainability and ethical practices, embrace Sustainable Practices, and collaborate with Suppliers and Customers to create more agile and efficient supply chains. Additionally, using Big Data Analytics might optimize production processes and augment supply chain efficiency while integrating Augmented Reality (AR) and Virtual Reality (VR) technologies potentially expand supply chain agility and efficiency. So, an agile and flexible supply chain process involves establishing a cross-functional team, developing a strategy, identifying potential bottlenecks, and leveraging technology. Despite its benefits, smart manufacturing presents several challenges, including security concerns, technical expertise, integration issues, and high initial investment. These are now the problems for the upcoming research in this field. However, researchers could also explore how supply chain risk strategies advance supply chain agility and resilience in smart manufacturing. This includes examining the potential benefits of using predictive analytics and other risk management tools to identify and mitigate supply chain risks. Likewise, researchers will investigate the potential benefits of adopting circular economy principles in smart manufacturing to promote sustainability, reduce waste, promote resource efficiency, and increase resilience. Nonetheless, leading toward improved product quality and customer satisfaction, smart manufacturing surprised the manufacturers to reduce costs by identifying areas of waste and inefficiency, optimizing production processes, and reducing the need for manual labor at an extended level.

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Chapter 3
Revolutionizing Supply Chain Management: A Bibliometric Analysis of Industry 4.0 and 5.0

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Abstract With the advancement of prediction, optimization, and automation, Industry 4.0 is characterized by integrating cutting-edge technology and creating smart factories. Industry 5.0 is a relatively new concept that focuses on integrating humans and machines to enhance the quality of products and services. Although the literature on this field has made progress in enhancing monitoring, tracking, and cost reduction, it has not devoted enough effort towards consolidating real justifications into a single framework. In order to make current industries more productive and efficient, this supply chain transformation, which arranged the manufacturing system, mechanized production, and substantial economic activity in revolutionary economies, must be organized. Thus, the authors use a systematic review approach to gather and analyze relevant literature for a transparent and rigorous view. This study also utilizes bibliometric analysis tools to identify key authors and publications in the field by comprehensively searching relevant databases and journals. In addition, this study incorporated the key challenges and opportunities for supply chain management based on these new technologies, including improved efficiency and transparency, but also possible problems with data security and worker displacement. As a result, this study contributes to detecting patterns and trends in the literature, such as the most popular research trend and the most popular research subjects, which will be helpful to academics and practitioners in supply chain management. Hence, the reviewed and revealed facts about the opportunities, problems, and realities may use to establish plans and laws addressing how Industry 4.0 and 5.0 will affect supply chain management in the future.

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Keywords Supply chain · Technology · Industry 4.0 · Industry 5.0 · Bibliometric analysis · Cost reduction · Systematic review approach · Worker displacement · Blockchain · Products and materials · Standards and compatibility · Cyberattacks

3.1 Introduction

Incorporating Industry 4.0 and 5.0 technologies throughout the supply chain has been a rapidly growing trend in recent years that supports companies in achieving increased efficiency, productivity, and flexibility (Mourtzis et al. 2022). According to recent research and industry publications, the technologies such as the Internet of Things (IoT), big data analytics, artificial intelligence (AI), robots, and blockchain, are altering supply chain operations and enhancing performance, cost-effectiveness, and customer happiness (Nair et al. 2021). These technologies also facilitate the transition to Industry 5.0, which emphasizes integrating human skills and collaboration with intelligent machines (Saniuk et al. 2022). To substantiate this, IoT sensors and data analytics could provide real-time information about inventory levels, demand patterns, and transportation routes, which facilitates companies to optimize their supply chain processes and reduce waste (Raja et al. 2023). Reverentially, with the adoption of Industry 4.0 and 5.0 technologies in the supply chain, production and logistics are expected to undergo significant changes in the future.

Yet, the capability of Industry 4.0 to allow real-time monitoring and control of the manufacturing process is one of its main advantages (Jiang et al. 2022). However, integrating these technologies has empowered manufacturers to create smart factories that operate autonomously, optimize production, and enhance quality control (Pereira et al. 2020). With IoT devices, for instance, sensors can be placed in critical areas of the production line to collect data on factors such as temperature, humidity, and pressure (Khan et al. 2023). This data is then analyzed by AI and ML algorithms to identify patterns, detect anomalies, and make predictive maintenance decisions (Raja Santhi and Muthuswamy 2023). Moreover, Industry 4.0 seamlessly integrates tools, systems, and processes, increasing output adaptability and productivity (Aheleroff et al. 2023). As a result, the industrial movement has dramatically benefited the direction of the manufacturing process.

To support this claim, blockchain might augment supply chain visibility and traceability, reduce fraud (Shamsuddoha and Kashem 2022), and improve sustainability by enabling transparent tracking of products and materials (Tyagi et al. 2023). So and so, manufacturers combine numerous systems and devices using cloud computing, allowing them to function in a coordinated and synchronized way (Jiménez López et al. 2022). Also, the development of digital twins, which are virtual representations of real assets, is made possible by this connection (Ruppert et al. 2022). However, with these digital twins, manufacturers replicate and improve manufacturing processes, save downtime, and cut waste. But, the absence of technology standards and compatibility is one of the main obstacles (Bakon et al. 2022). As a result, manufacturers struggle to integrate various technologies from various vendors,

which raises prices and complicates things. Furthermore, there are concerns about data security and privacy and the potential for cyberattacks due to the vast data collection. It is now appropriate to reprise these processes to take advantage of the best market possibilities and create a win–win scenario for the supply chain and manufacturing.

3.2 Human–Machine Collaboration and Supply Chain Management

Advancements through human–machine collaboration are transforming the supply chain industry, improving efficiency and reducing costs (Mourtzis et al. 2022). On the other hand, IoT sensors are being integrated into supply chain management systems, providing real-time data on inventory levels (Zizic et al. 2022) and helping companies anticipate and prevent supply chain disruptions (Menezes et al. 2022). In connection, AI-powered predictive analytics might assist in forecasting demand and prevent disruptions (Mourtzis et al. 2022), while autonomous vehicles and drones can streamline logistics and delivery (Bedi et al. 2021; Hofmann and Rüsch, 2017; Pizoń and Gola 2022). Similarly, machine learning (ML) algorithms are also being used to optimize shipping routes, reducing delivery times and fuel costs (Sołtysik-Piorunkiewicz and Zdonek 2021), and even forecasting accuracy (del Real Torres et al. 2022). For instance, companies like Amazon and Walmart already use them in some regions and may witness such an increase. Hence, human–machine collaboration advances improvement in the supply chain.

At the forefront of this advancement, from predictive analytics to autonomous robots, technology is transforming the way we manage and optimize supply chains. Collaborative robots or "cobots" are being deployed in warehouses and distribution centers to help human workers with tasks such as picking and packing (Aquilani et al. 2020; Kadarisman et al. 2022). However, the use of robots in warehouses and distribution centers is increasing (Jiang et al. 2022), with companies like Alibaba and Amazon deploying thousands of them. Likewise, cloud-based platforms enable real-time visibility and inventory tracking (Bakon et al. 2022). Similarly, blockchain is used for transparency and security in supply chain transactions (Tyagi et al. 2023), augmented reality to train workers and improve quality control (Trehan et al. 2022) and 3D printing to reduce lead times and costs for certain products (Thomaz and Bispo 2022). So, all these technologies collaborate with humans to improve supply chain efficiency and effectiveness, reduce costs, and enhance customer experiences. With these advancements, the supply chain industry is poised to become more efficient, transparent, and sustainable. Therefore, this adaptability helps firms respond swiftly to shifting consumer expectations, which boosts their competitiveness and profitability.

Table 3.1 highlights various opportunities and implications of using smart technologies in manufacturing. Predictive maintenance might reduce downtime and

inventory costs, while real-time inventory tracking and autonomous material handling improve supply chain management and increase efficiency. In addition, demand sensing and dynamic pricing optimize production and pricing, while collaborative planning and supply chain helps reduce disruptions and delays. Moreover, automated quality control ensures better quality products and traceability through blockchain technology improves transparency. Energy optimization through IoT sensors and machine learning algorithms aided in reducing energy expenses and increasing sustainability.

Table 3.2 abridges the technology advancements, improvements, and cost reductions associated with Industry 4.0 and 5.0. Industry 4.0 is characterized by increased automation, better connectivity, and real-time data analysis, improving productivity, resource management, and safety. In contrast, Industry 5.0 emphasizes greater collaboration between humans and machines, advanced manufacturing techniques, and customization, resulting in improved product quality, design, and customer experience, as well as reduced costs and increased efficiency.

3.3 Movement of Industrial Revolution: From Industry 4.0 to 5.0

Disruptive technologies like Industry 4.0 and Industry 5.0 are changing how firms conduct their operations. Generally, Industry 4.0 uses advanced automation and data analysis tools to improve productivity (Alsamhi et al. 2022; Kucharcikova et al. 2022; Thiyagarajan and Harish 2023), more specifically, boost production (Tumentsetseg and Varga 2022) with lowering maintenance costs (Alhajjar et al. 2018; Granrath 2019; Marica and Bizon 2022; Menezes et al. 2022; Rahman et al. 2020; Vogt 2021) and energy usage (Salimova et al. 2020), even advancements in supply chain management (Diop et al. 2022). In contrast, Industry 5.0 revolutionizes manufacturing by enabling greater collaboration between humans and machines (Tumentsetseg and Varga 2022) with highly personalized items using cutting-edge methods (Awotunde et al. 2023; Kadarisman et al. 2022; Østbø et al. 2022). According to the report, Industry 5.0 may result in lower material prices, lower production costs, and shorter lead periods (Lachvajderová and Kádárová 2022; Thomaz and Bispo 2022). Consequently, this approach may result in highly tailored and personalized goods as well as more effective and efficient manufacturing procedures.

3.4 Methodology

This research uses a qualitative approach to understand how supply chain optimization will change as Industry 4.0 and 5.0 resolve defects. According to Fosso Wamba and Mishra (2017), the research is guided by a bibliometric analysis methodology

Table 3.1 Opportunities and implications for supply chain

Keys	Opportunities and implications
Predictive maintenance	Using sensors and data analytics, smart factories predict when machines need maintenance or replacement parts, reducing downtime and ensuring that production is more efficient (Nair et al. 2021). It allows for better inventory management, reducing the risk of stockouts or overstocking (Zengin et al. 2021)
Real-time inventory tracking	Smart factories use RFID tags or other tracking technologies to monitor inventory in real-time, allowing for more accurate and efficient supply chain management (Zambon 2022) to reduce the risk of stockouts and ensure that inventory is available when needed
Autonomous material handling	Using robots and autonomous vehicles allows transporting of materials and goods within the factory and across the supply chain to reduce the need for human labor and improve safety, increasing efficiency and reducing costs (Xu et al. 2021)
Demand sensing	Through machine learning algorithms, it is easy to analyze data from various sources, such as social media, weather forecasts, and sales data, to predict product demand (Aheleroff et al. 2023). To optimize production and inventory levels, reduce waste and ensure that products are available when customers need them (Jiménez López et al. 2022)
Collaborative planning	Collaboration with suppliers, customers, and other stakeholders in the supply chain, improving communication and coordination (Banholzer 2022) for better planning and forecasting, and reducing the risk of disruptions and delays are possible using digital platforms
Automated quality control	Smart factories use AI-powered vision systems to inspect products for defects, reduce the need for manual inspection, and improve quality control (Tyagi et al. 2023)
Dynamic pricing	To adjust prices dynamically to enable manufacturers to optimize pricing and maximize profits, the real-time data on production costs, inventory levels, and customer demand by the industrial revolution (Bakon et al. 2022)
Collaborative supply chain	The interconnection among suppliers, distributors, and retailers is necessary to create a collaborative supply chain for real-time communication and coordination, improving efficiency and reducing costs (Tran et al. 2022)
Traceability	Through blockchain technology, we can create a tamper-proof record of every step in the manufacturing process (Kaur et al. 2022) and enables manufacturers to track products from raw materials to the end user, improving transparency and traceability
Energy optimization	Energy usage is optimized using IoT sensors and machine learning algorithms to reduce energy expenses and increase sustainability

drawn from the literature. This paradigm aided in the paper's organization within the constraints of systematic reviews. Network analysis is used to speed up supply chain movement and progress research. Still, the study questions focused on the more exact acceleration of the supply chain with the introduction of industry 4.0 and 5.0 technologies. The research combines network analysis and bibliometric analysis

Table 3.2 Possible advances, improvements and cost reduction by Industry 4.0 and 5.0

Technology	Advancements	Improvements	Cost reduction
Industry 4.0 (Alvarez-Aros and Bernal-Torres 2021; Aquilani et al. 2020; Fathi et al. 2019; Potočan et al. 2020; Salimova et al. 2020; Sudibjo et al. 2019)	Increased automation, better connectivity and communication, real-time data analysis and predictive maintenance	Improved productivity, better resource management, reduced downtime, improved safety and quality control	Reduced labor costs, optimized energy consumption, reduced waste and material costs
Industry 5.0 (Grabowska et al. 2022; Lachvajderová and Kádárová 2022; Madhavan et al. 2022; Margherita and Braccini 2021; Ruppert et al. 2022; Souza et al. 2022)	Greater collaboration between humans and machines, improved customization and personalization, use of advanced materials and manufacturing techniques	Improved product quality and design, faster time-to-market, and enhanced customer experience	Reduced material and production costs, improved efficiency and speed

to concentrate on the importance of the supply chain through industry 4.0 and 5.0 technology development applications. The study topics (Table 3.3) investigate how supply chain operations are impacted by industry 4.0 and 5.0 intelligence roles.

In order to find pertinent literature, the authors employed databases and keyword rationale in the review analysis, focusing on highly cited, high-quality papers for the initial investigation. The study used references from the most frequently referenced works to increase visibility. Nevertheless, to review previous supply chain management studies relevant to industries 4.0 and 5.0, this systematic qualitative assessment used a clearly defined search strategy, a reliable repository, and exact inclusion and exclusion criteria (Table 3.4).

Table 3.5 lists the number of publications about Industry 4.0 and 5.0 and the supply chain. The number of articles relating to Industry 4.0 and 5.0 and the supply chain are shown in Table 3.5. The data is obtained from various search engines, including Google Scholar, PubMed, and Scopus. However, the result of a search using the keywords "industry 4.0," "industry 5.0," or "supply chain" on Google Scholar returned 51,200 papers, including citations, with no specific inclusion or exclusion parameters. This means that the search results included papers that mention the keywords anywhere in the article, including the abstract, introduction, and conclusion. The search returned 9330 papers with the keywords inclusion parameter of the article's title. With the keywords "industry 4.0 and 5.0," the search returned 114 papers that meet these criteria without including citations of 87 papers. Again, the result of searches on PubMed using the keywords "industry 4.0 and supply chain" and "industry 5.0 and supply chain" returned 102 and 27 papers, respectively, with the keywords mentioned in the title. The table shows the result of searches on Scopus using the keywords "Industry 4.0" and "Industry 5.0," the searches returned 62 and 3 papers, respectively. The search results suggest significant interest in these topics among researchers, with thousands of papers published on the relevant subjects.

Table 3.3 Research question and contribution

Research gap	Research question	Contribution to industry
Inadequate knowledge of the supply chain management about technology's complete promise for Industry 4.0 and Industry 5.0	How can supply chain management procedures be more efficient using Industry 4.0 and 5.0 technologies?	Identification of key areas, such as predictive maintenance, real-time tracking, and autonomous logistics, where Industry 4.0 and 5.0 may enhance supply chain management
Uncertainty about Industry 4.0 and 5.0 affecting worker dynamics and job displacement	What possible effects may Industry 4.0 and 5.0 have on the labor market, supply chain employees, and other factors?	Analysis of prospective workforce changes, including the need for new training and skills, the possibility of job creation, and the demand for new skills
There is little information on the execution difficulties and supply chain management acceptance of Industry 4.0 and 5.0	What are the primary obstacles to supply chain management using Industry 4.0 and 5.0 technologies?	Implementation obstacles such as infrastructure needs, data management, and cyber security
Insufficient research has been done on how Industry 4.0 and 5.0 will affect supply chain management regarding ethics and society	How can supply chain management consider the ethical and societal ramifications of Industry 4.0 and 5.0, including concerns about data protection, transparency, and sustainability?	Identification of moral and societal issues of supply chain management adoption and application of Industry 4.0 and Industry 5.0, as well as the creation of mitigation plans for any possible drawbacks

Table 3.6 of citation metrics contains several metrics relevant to the articles published during this period and gives bibliometric data for a specific publishing period and citation period. The information relates explicitly to research articles published between 2010 and 2023 and the citations those publications earned throughout that same time. Out of the lists, there were 130 publications overall that garnered 481 citations published throughout the period. Again, the average number of citations each year was 37, while the h-index and g-index values were 8 and 15, respectively. This study uses Fosso Wamba and Mishra's (2017) guidelines to consider databases and keywords for bibliometric analysis. Also, VOSviewer is used for graph visualization, studying author cooperation networks for academic work, and looking into author clusters in addition to presented data and network analysis. (Rejeb et al. 2020). In this instance, Figs. 3.1, 3.2 and 3.3 show cluster analysis and early network studies for connections of all co-authors and writers in a group, respectively.

Figures 3.1, 3.2 and 3.3 bear such relevance that they have paved the way for the emergence of Industry 4.0, a new era of innovation that has sparked immense interest in the digital transformation of supply chain activities. Industry practitioners and researchers are increasingly focusing on Industry 4.0-enabled technologies. Most

Table 3.4 Inclusion and exclusion parameters

Inclusion parameters	Exclusion parameters
1. English-language peer-reviewed studies from 2010 to the present that has been published in conference proceedings or journals	1. Research papers not released as conference proceedings or peer-reviewed publications
2. Research on how Industry 4.0 and 5.0 affect the supply chains in many industries, including manufacturing, logistics, transportation, retail, and healthcare	2. Research papers are written in languages other than English
3. Research on the advantages and difficulties of applying Industry 4.0 and Industry 5.0 to supply chain activities such as inventory management, production planning, quality control, and distribution	3. Research that is irrelevant to how Industry 4.0 and 5.0 will affect the supply network
4. Research how modern technologies like blockchain, AI, the IoT and robots could boost the efficacy and efficiency of the supply chain	4. Research examining other dimensions of Industry 4.0 and Industry 5.0, especially truly technical papers
5. Studies of Industry 4.0 and Industry 5.0 that covered supply chain efficiency, including cost savings, lead time savings, and customer satisfaction	5. Outdated studies that don't accurately reflect the standing of the industry today

Table 3.5 Selection of manuscripts

Keywords/search string	Search engine	No. of papers	Inclusion and exclusion parameters
"Industry 4.0, or Industry 5.0, OR supply chain"	Google Scholar	51,200 (incorporating citations)	Anywhere in the articles
"Industry 4.0, or 5.0, or Supply Chain."	Google Scholar	9330	Title of the article
"Industry 4.0 and/or 5.0"	Google Scholar	130	Title of the article
"Industry 4.0 and 5.0"		114	Title of the article (Including citations)
"Industry 4.0 and 5.0"	Google Scholar	87	Title of the article (Excluding citations)
"Industry 4.0 and Supply Chain"	PubMed	102	Title of the article
"Industry 5.0 and Supply Chain"	PubMed	27	Title of the article
Industry 4.0	Scopus	62	Title of the article
Industry 5.0	Scopus	3	Title of the article

Table 3.6 Citation metrics

Publication year	Citation year	Papers	Citations	Cites/ year	Cites/ paper	Author/ paper	h-index	g-index
2010–2023	2010–2023	130	481	37.00	3.70	2.25	8	15

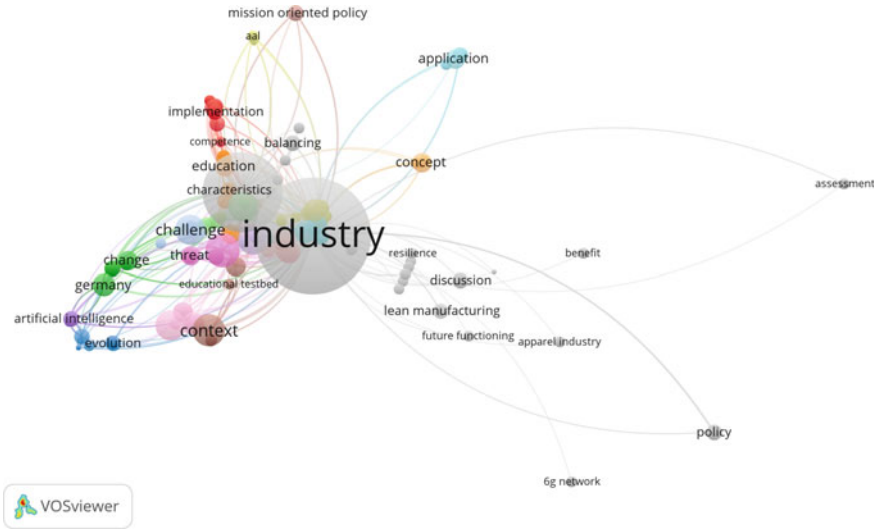

Fig. 3.1 Cluster analysis

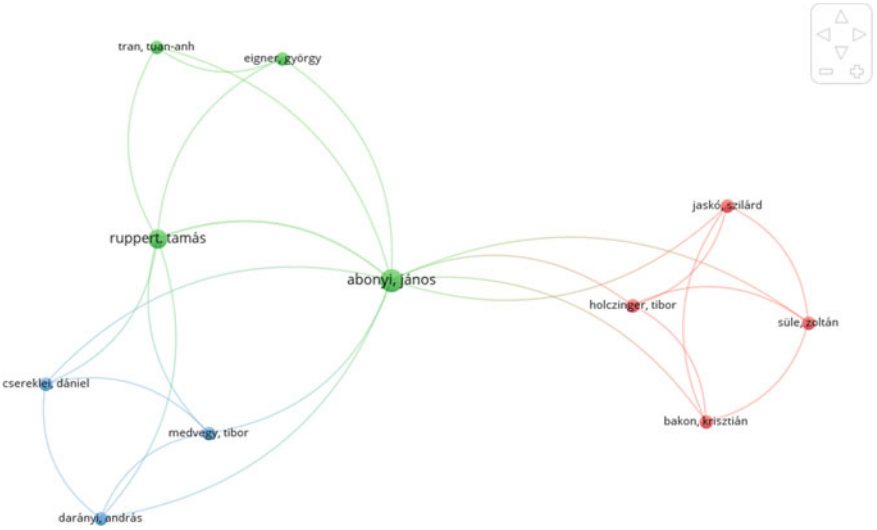

Fig. 3.2 Network visualization of authors in group

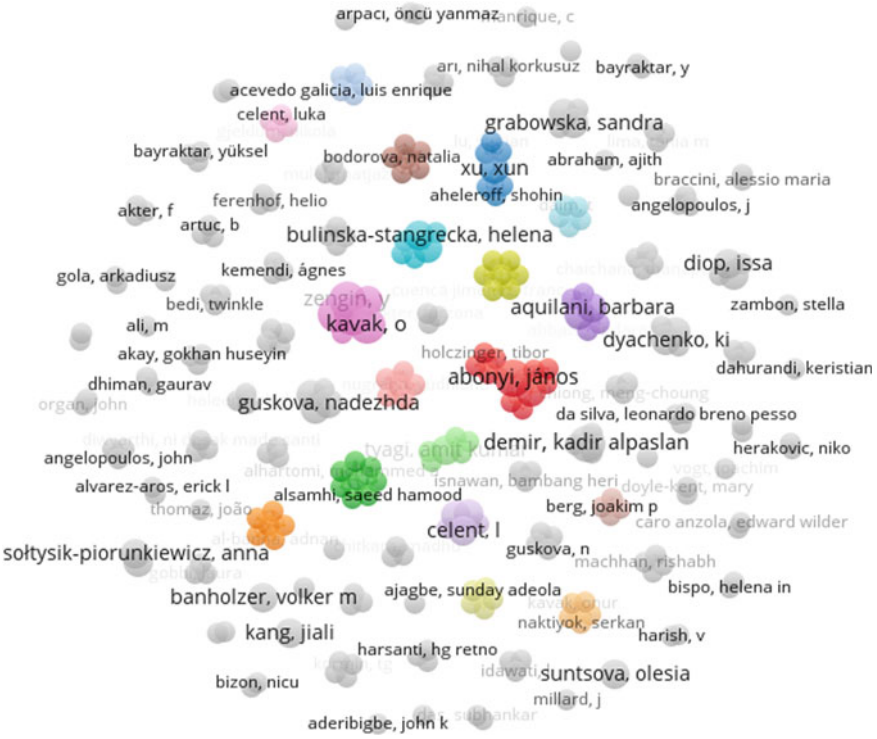

Fig. 3.3 Network visualization of all authors

review articles have been crafted with the aid of systematic or comprehensive literature surveys, often showcased in prestigious journals or specialized fields. However, a bibliometric analysis tool and technique could provide a broader view of the decade of research in this area. Therefore, an extensive bibliometric analysis was carried out using database articles to examine the data, find study trending subjects, and establish a knowledge foundation. The results showed that "industry" and "society" were emerging themes in the field, while "opportunity", "application", "policy", "practice," and "challenges" were hot issues. The report also identified areas for further research and the field's potential scope.

The low degree of homophily between nodes in the authors' cluster suggests weak connections and a great distance between clusters. The multidimensional viewpoints of new technologies have been constrained; as a result, the limited chances of "similarity breeds connection" through citation analysis. To grasp the full potential of these technologies in the early stages of supply chain operations, it is imperative to conduct a thorough review of the industry shift towards the innovative realms of industries 4.0 and 5.0. However, from the databases, the major contribution of these manuscripts was from Novikov (2017), Dravica and Kurbatsky (2016), Kulikov et al. (2019), Maslennikova (2019). This innovative revolution has a qualitative leap of

promising industrial policy (MITI 2018) and development for digitization (Dravica and Kurbatsky 2016) and updating the information systems (Kulikov et al. 2019). Once more, in order to meet the difficulties of Industry 4.0's digital transformation, it is essential to enable electronic contact between the state and society based on new options for remote involvement, decision-making, and control (Maslennikova 2019; Zhao and Liu 2016).

For instance, the proportion of businesses with a high degree of digitization is currently approximately 33% and is predicted to reach 72% within the next five years (Novikov 2017). This innovative revolution has a qualitative leap of promising industrial policy (MITI 2018) and development for digitization (Dravica and Kurbatsky 2016) and updating the information systems (Kulikov et al. 2019). Yet again, aiming to overcome the challenges posed by the digital change of Industry 4.0, it is essential to enable electronic contact between the state and society based on new options for remote involvement, decision-making, and control (Maslennikova 2019; Zhao and Liu 2016).

3.5 Contribution of Industry 4.0 and Industry 5.0

3.5.1 Supply Chain Monitoring and Tracking

Recent years have seen a fast advancement in technology, leading to the emergence of industries 4.0 and 5.0. Supply chain management has been significantly impacted by these shifts, especially with regard to recording, monitoring, and cost-cutting (Alhajjar et al. 2018; Granrath 2019; Marica and Bizon 2022; Menezes et al. 2022; Rahman et al. 2020; Vogt 2021). Here, we will contrast how these critical facets of supply chain management have developed and improved with Industry 4.0 and 5.0.

From the above comparison (Table 3.7), while Industry 4.0 has already significantly improved supply chain monitoring, tracking, and cost reduction, Industry 5.0 takes these advancements even further. With advanced robotics, AR, and the cloud, companies might achieve greater visibility and control over their operations, resulting in even more significant cost savings and efficiency gains.

3.5.2 Supply Chain Transformation, Automated Production and Factory System

Recently, the business world has paid a lot of attention to the concepts of Industry 4.0 and Industry 5.0. Industry 4.0 and 5.0 are altering supply network administration and improvement. This study aims to document the supply chain transformations in Industry 4.0 and 5.0, enabling future comparisons and evaluations.

Table 3.7 Supply chain monitoring and tracking

Industrial movement	Monitoring and tracking	Significant contribution
Industry 4.0 (Alvarez-Aros and Bernal-Torres 2021; Aquilani et al. 2020; Fathi et al. 2019; Glukhov et al. 2017; Potočan et al. 2020; Salimova et al. 2020; Shevtsova and Maslosh 2019; Sudibjo et al. 2019; Yuniarto et al. 2020)	IoT, real-time data analytics, and AI have changed supply chain monitoring and tracking. IoT devices such as sensors and RFID tags monitor and transmit data on various variables, including temperature, location, and movement. AI algorithms then analyze this data in real-time, providing insights into performance and efficiency that were previously impossible to achieve	Supply chain management has experienced substantial expense reductions due to Industry 4.0. Real-time data analytics and AI algorithms allow companies to optimize their operations, reducing waste and increasing efficiency. This has resulted in lower transportation costs, reduced inventory costs, and fewer production errors
Industry 5.0 (Grabowska et al. 2022; Lachvajderová and Kádárová 2022; Madhavan et al. 2022; Margherita and Braccini 2021; Ruppert et al. 2022; Souza et al. 2022)	Industry 5.0 takes these advancements even further by introducing advanced robotics, augmented reality (AR), and the use of the cloud. This technology allows for greater visibility and control over the entire supply chain, enabling companies to identify and quickly address potential issues	Using cutting-edge robotics and augmented reality (AR) technology, Industry 5.0 allows businesses to automate further and simplify their processes, which lowers labor costs and boosts productivity

Table 3.8 compares Industry 4.0 and Industry 5.0 regarding their objectives and focus. Industry 4.0 aims to digitize and automate industrial processes to create a smart factory using advanced technologies, leading to cost savings, improved customer satisfaction, and better responsiveness to changes in demand. On the other hand, Industry 5.0 builds upon Industry 4.0 by highlighting the importance of creating a personalized and human-centered production process to leverage the strengths of both humans and robots to enhance the supply chain.

3.6 Potential Issues with Data Security and Workforce Displacement of Industrial Revolution

The fourth and fifth industrial revolutions, which are defined by the fusion of cutting-edge technologies, have the following possible cyber security problems.

In Table 3.9, various critical issues related to cybersecurity and data privacy in the supply chain are outlined. These include the susceptibility of the supply chain to cyber threats, the importance of safeguarding sensitive data produced and exchanged throughout the supply chain, the danger posed by external suppliers, the absence of uniform security procedures, and the possibility of human mistakes resulting in

Table 3.8 Digitization, automation and industrial movement

Industrial movement	Industry 4.0	Industry 5.0
Digitization and automation	The primary objectives of Industry 4.0 are the digitization and automation of the industrial process that entails creating a networked, self-optimizing smart factory using cutting-edge technologies (Pereira et al. 2020). Businesses possibly save costs, improve consumer satisfaction generally, and respond to changes in demand more quickly as a result due to this transformation in the supply chain (Xu et al. 2021)	Industry 5.0 advances Industry 4.0 by emphasizing the value of human–machine cooperation that might contribute to developing a more individualized and human-centric production process (Saniuk et al. 2022). However, companies may use the advantages of both humans and robots in the context of supply chain transformation to enhance the whole supply chain

data breaches. As a result, securing the supply chain's data in Industry 4.0 and 5.0 necessitates a comprehensive strategy encompassing robust cybersecurity measures, data privacy protocols, vendor management, and employee education.

Table 3.9 Potential issues of the industrial revolution

Cyber security (Khan et al. 2023)	The more connected a supply chain is, the more vulnerable it is to cyber-attacks. Cybercriminals may target any part of the supply chain, from supplier to manufacturer to distributor, steal sensitive information, disrupt operations, or sabotage equipment. It is crucial to implement robust cybersecurity measures to protect against these threats
Data privacy (Alsamhi et al. 2022)	A significant quantity of data is created and exchanged across the supply chain using connected devices and sensors in Industry 4.0. Sensitive information includes trade secrets, client information, and financial data, which is crucial to treat with care and shield against illegal access or exposure
Supplier risk (Jiang et al. 2022)	Companies are exposed to increased risks as they depend more on partners and third-party providers for products and services. Suppliers might purposely or accidentally undermine data security through their conduct or have lax security practices that make them more open to assaults
Lack of standards (Ruppert et al. 2022)	With the rapid development of new technologies, there is often a lack of standardized security protocols and best practices, making it challenging for companies to know what measures to implement and how to ensure they are effective
Human error (Rahman et al. 2020)	Human error can still lead to data breaches even with the best security measures. Employees may accidentally share sensitive information, fall victim to phishing scams, or fail to follow security protocols, so training employees on security awareness and best practices is essential

3.7 Summary Advancements of Supply Chain Through Industry 4.0 and Industry 5.0

The following section provides an overview of the progress in the supply chain utilizing the concepts of Industry 4.0 and 5.0.

3.7.1 Industry 4.0

The tentative contributions of Industry 4.0 at a glance are as follows:

- Implementing IoT-enabled sensors and devices to monitor inventory levels, optimize warehouse space, and reduce waste by enabling just-in-time inventory management.
- Leveraging real-time analytics and predictive maintenance to optimize equipment and machinery, reducing downtime and maintenance costs and improving production efficiency.
- Utilizing blockchain technology to improve supply chain transparency, traceability, and accountability reduces the risk of fraud, theft, and counterfeit products.
- Incorporating AI and ML algorithms to analyze and improve supply chain operations, such as demand forecasting, spotting bottlenecks, and foreseeing disruptions.
- Improving logistics and lowering transportation costs by allowing quicker, safer, and more effective delivery of products using drones and autonomous vehicles.
- Using augmented reality (AR) and virtual reality (VR) technology to give warehouse employees and supply chain experts immersive training and support, lowering human error and raising efficiency.
- Adopting cloud-based platforms to improve collaboration and communication across supply chain partners, enabling faster decision-making and reducing administrative costs.
- Creating digital twins of physical assets and processes to simulate and optimize supply chain operations, enabling continuous improvement and reducing the risk of costly errors.

3.7.2 Industry 5.0

The tentative contributions of Industry 5.0 at a glance are as follows:

- Implementing Real-Time Data Analytics: Industry 5.0 could use real-time data analytics to monitor and track every stage of the supply chain. This technology might assist companies in identifying bottlenecks, optimizing operations, and improving overall efficiency, ultimately reducing costs.

- Autonomous Vehicles for Transportation: Industry 5.0 might introduce autonomous vehicles to the supply chain, which might help reduce the costs associated with manual labor and transportation. This technology might also improve delivery times, reduce the risk of accidents, and optimize routing for more efficient transportation.
- Blockchain Technology for Transparency: Industry 5.0 might introduce blockchain technology to the supply chain, improving transparency and reducing the risk of fraud. This technology might create a tamper-proof record of every transaction, making tracking products from the source to the consumer easier.
- AI-powered Supply Chain Optimization: Industry 5.0 might leverage artificial intelligence to optimize the supply chain by predicting demand, optimizing inventory, and reducing waste. AI-powered systems might also monitor the condition of products in real-time, reducing the risk of spoilage and damage.
- Smart Sensors for Condition Monitoring: Industry 5.0 might introduce smart sensors to the supply chain, which might monitor the condition of products in real time. This technology might detect changes in temperature, humidity, and other environmental factors, helping companies to take proactive measures to prevent spoilage and damage.

To establish the transformation between Industry 4.0 and 5.0, future supply chain processes' potential benefits could be articulated under the dimensions of smart warehouses, digital supply chains, and the adoption of circular supply chain models. More specifically, Industry 4.0 concepts might be integrated with supply chain processes by using smart warehouses equipped with automated robots, IoT sensors, and RFID technology to increase efficiency and reduce labor costs. In contrast, Industry 5.0 concepts might further enhance this by introducing collaborative robots that work alongside human workers and adapt to their needs. Again, Industry 4.0's digital supply chain concepts might be improved by Industry 5.0's human–machine collaboration, allowing companies to use human expertise to create more efficient and effective digital supply chain processes that meet the needs of their customers. However, integrating IoT devices supports establishing a more connected and data-driven supply chain process. These devices provide real-time data on product location, temperature, and condition, which might aid in optimizing logistics and improving quality control. Adopting circular supply chain models assists in establishing a more sustainable and resilient supply chain process. These models focus on reducing waste and promoting reusing and recycling materials and products. Nevertheless, sustainability in the supply chain benefits businesses by reducing their environmental impact and improving their reputation by using renewable energy, reducing waste, and using eco-friendly materials. So, the potential benefits of using sustainable practices include improved brand image, reduced costs, and increased customer loyalty.

3.8 Conclusion

Generally speaking, industry 4.0 is the continued trend of automation and data interchange in manufacturing technology. On the other hand, Industry 5.0 is a more recent idea emphasizing the value of individualized manufacturing and human–machine collaboration. Like Industry 4.0, industry 5.0 offers opportunities for increased productivity, efficiency, and cost savings through cutting-edge technologies like AI, IoT, and robotics. These opportunities might increase customer satisfaction and loyalty while also allowing for the creation of more individualized and customized products. But there may be chances for fresh company strategies and sources of income in both Industry 4.0 and Industry 5.0. However, implementing Industry 4.0 and 5.0 technologies might be costly and require a sizable investment in infrastructure and training. Concerns have also been raised regarding how automation could affect employment, as it might result in job losses in some sectors. As the usage of connected devices increases, more potential weaknesses for cyberattacks are created, raising worries about cyber security and data privacy. Therefore, in reality, this industrial revolution is already well started in many industries, notably in the field of the supply chain, with many businesses implementing automation and data-driven technology to boost productivity. These could now be the future scholars' study priorities. Furthermore, proper planning and management will be necessary to reap the benefits and reduce possible drawbacks.

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Chapter 4
Supply Chain Resilience: A Literature Review and Gap Analysis

Farida El-naggar and Mona Ali Ali

Abstract A series of unprecedented shocks is currently straining global supply chains, especially after COVID 19 and Russian Ukrainian war, resulting in many supply chain disruptions. These disruptions pose threats not only to organizations but also to country economies worldwide. Supply chain resilience (SCRes) is a key capability which enhances the performance of supply chains and minimizes the response time leading to supply chain recovery. Although there is extensive research on SCRes, there is still ambiguity regarding the topic. In addition, there is a lack of consensus on SCRes approaches. In this study, a systematic literature review is conducted to fill in this gap. The literature review will aim to answer questions related to the main definitions, features, types, measures, theories, relationships and effects of SCRes strategies on supply chain performance. This study presents a holistic view in addition, it highlights the main gaps in SCRes literature enabling academic community to examine these gaps in the future. The results of the systematic review confirm that there are numerous gaps in the literature. One of the gaps found is concerned with consensus about the general definition of SCRes. Each study in the literature defines SCRes based on the context of the study. Another gap is concerned with the measures of SCRes, where many measures are found in the literature without a structured methodology to adopt measures. Additionally, a theoretical gap was found where most of the studies adopted the resource based view and the dynamic capability theories conceptually without differentiating between resources, capabilities and the different phases of the dynamic capability theory. Finally, the last gap found is that most of the studies in the literature use cross sectional approaches for their empirical data collection with little regards to the importance of longitudinal data collection methods and its ability to reflect successful adoption of SCRes strategies.

Keywords (SCRes) · Dynamic capabilities (DCs) · SC disruptions · SC performance (SCP) · Gap analysis

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4.1 Introduction

The Covid-19 pandemic had a negative impact on global supply chains, with notable changes in demand between countries that depend on imports from the east as well as major repercussions on production, sourcing, manufacturing, processing, and logistics. Especially, After the Russian-Ukrainian war, many nations that depend on wheat have faced shortages in the past year. For example, Egypt obtains two-thirds of their wheat supply from these countries. This is because both countries are major producers of agricultural commodities on a global scale. According to World Food Program, 9.1% of the world's wheat exports come from Russia and 3.2% of the world's wheat is produced in Ukraine. Russia is the top-ranked wheat exporter in the world, and Ukraine is the fifth-ranked exporter and a major wheat supplier (Jagtap et al. 2022). SCRes is proposed as a strategy adopted to mitigate the risk of such disturbances, allowing smooth flow of supplies. Although there has been a myriad of studies about SCRes, there is still some ambiguity involved in its nature and effect. This study attempts to solve some of these ambiguous features highlighting the main definitions, features, types, measures and effects of SCRes. The author also presents the main gaps in SCRes literature enabling their examination in the future.

4.2 Review of Literature

In this section, the studies related to SCRes definitions, measures, theories and relationships will be discussed leading to the main gaps in the literature.

4.2.1 Definitions of Supply Chain Resilience

SCRes is a multidisciplinary, multidimensional, and hierarchical concept and there is no consensus on defining SCRes. The major SCRes definition elements are: focus event; adaptive framing or adaptive response; speed; value added; cost effectiveness; performance level and a key factor for a sustainable supply chain advantage (Ribeiro and Barbosa-Povoa 2018). Table 4.1 presents the historical evolution of the definitions found in the literature for SCRes.

From the above definitions, it is evident that SCRes is an adaptive capability, dynamic, a continous sustainable act, a comprehensive function, encompasses three main phases; readiness, response and recovery.

Table 4.1 Supply chain resilience definitions

Authors	Definitions of supply chain resilience
Rice and Caniato (2003)	The capacity to respond to unforeseen disruptions and resume regular supply network operations in the supply network environment
Rice et al. (2003)	Being able to respond to sudden disruptions and resume regular supply network operations
Closs et al. (2004)	Being capable to endure an event and recover from it. A robust supply chain is proactive, anticipating potential problems and setting up a plan to address them. When involved in an incident, such a supply chain immediately establishes alternative ways of operation
Christopher and Peck (2004)	The supply chain's capacity to recover from disturbances and transition to a new, more desired state is known as SCRES
Christopher and Rutherford (2004)	The capacity of a system to change after being perturbed, either to a new, preferable state or to revert to its initial condition or the capability of a system to recover from a disturbance and resume its initial (or desired) state is known as resilience
Closs and McGarrell (2004)	The supply chain's resilience to incidents and ability to recover from them is known as SCRES. A robust supply chain is proactive, foreseeing potential problems and setting up a plan to address them. When involved in an incident, these supply chains immediately establish other ways of operation
Sheffi (2005)	When referring to the corporate world, resilience is the capacity of the organization to recover from a significant disruption, including the speed at which it resumes regular levels of performance
Datta (2007)	SCRES is a characteristic of being adaptive and capable of sustained reaction to abrupt and major shifts in the environment in the form of unpredictable demands. It is not simply the ability to maintain control over performance variability in the face of disruption
Gaonkar et al. (2007)	The capacity to continue operating after an interruption and to do so successfully
Gaonkar and Viswanadham (2007)	A supply chain's ability to maintain, carry on, and resume operationsafter a disruption is referred to as SCRES
Datta et al. (2007)	Along with the capability to maintain control over performance variability in the face of disruption, adaptability refers to the capacity to sustain responsiveness to environmental changes that occur suddenly and significantly, such as unpredictable demands
Falasca et al. (2008)	A supply chain system's ability to lessen the likelihood of disruptions, to lessen their effects, and to accelerate the return to normal performance

(continued)

Table 4.1 (continued)

Authors	Definitions of supply chain resilience
Falasca (2008)	SCRES refers to a supply chain's capacity to decrease the likelihood of a disruption, to lessen the effects of those disruptions when they do occur, and to accelerate the return to normal performance
Longo and Oren (2008)	In the context of supply chain change management, resilience is a crucial characteristic that enables the supply chain to respond to internal and external risksand vulnerabilities, swiftly regaining an equilibrium state that can provide high performance efficiencylevels
Ponomarov et al. (2009)	SCRes is the adaptive capability to plan for unforeseen events, respond to disruptions, and recover from them by ensuring operations continue at the desired level of connectivity and structural and functional control
Ponomarov and Holcomb (2009)	SCRES refers to the supply chain's adaptive capacity to anticipate unforeseen occurrences, respond to disruptions, and recover from them by ensuring operations continue at the required degree of connectivity and control over structure and function
Barroso et al. (2010)	SCRES is the supply chain's capacity to respond to the detrimental impacts brought on by disturbances that happen at a specific time in order to uphold the supply chain's goals
Erol et al. 2010	Concerned with the system's capacity to recover from disturbances and move to a new, preferable state while preventing failure modes from occurring. The capacity to adapt and respond to unanticipated changes and disturbances is referred to as resilience
Guoping and Xinqiu (2010)	The ability of the supply chain to resume its initial or ideal state in an emergency risk scenario is known as SCRES
Pettit et al. (2010)	Resilience in the supply chain is the capacity to endure, adapt, and advance in the face of disruptive change
Jüttner et al. (2011)	SCRes is predicated on the underlying presumption that not all risk events can be prevented, some supply chains appear to be able to recover from inevitable risk occurrences more successfully than others
Shuai et al. (2011)	Resilience is described as the ability to quickly return to equilibrium following a disturbance that attacks the supply chain, and we use the recovery time to gauge the ability
Carvalho et al. (2011)	In order to prevent failure modes from occurring, SCRES is concerned with the system's capacity to return to its initial state or to a new, more desirable one after experiencing a disruption
Carvalho et al. (2012a, b)	The ability of a company's supply chain to adapt, to anticipate events, to deal with interruptions, and to quickly recover from them by ensuring that activities continue at the required level of connectedness and under control in terms of structure and function.,

(continued)

Table 4.1 (continued)

Authors	Definitions of supply chain resilience
Ponomarov (2012)	Supply chain resilience refers to a company's supply chain's ability to adapt in order to anticipate unanticipated occurrences, respond to disturbances, and quickly recover from them by ensuring operations continue at the required level of connection and control over structure and function. The capacity of the supply network to deal with unforeseen disruptions
Xiao et al. (2012)	Adaptability to the environment and disruption recovery are both parts of SCRES, which refers to the supply chain's capacity to resume its initial or ideal state following an external disruption
Carvalho et al. (2012b)	SCRES refers to the supply chain's capacity to deal with unforeseen disruptions
Ponis et al. (2012)	The ability to proactively plan and design the supply chain network for anticipating unanticipated disruptive (negative) events, respond adaptably to disruptions while maintaining control over structure and function, and transcend to a robust post-event state of operations, if possible, more advantageous than the one prior to the event, thus gaining competitive advantage
Yao and Meurier (2012)	Resilience in the supply chain is the capacity to recover from setbacks and adapt consistently to changing conditions
Ponis and Koronis (2012)	The ability to proactively plan and design the supply chain network for anticipating unanticipated disruptive (negative events), respond adaptably to disruptions while maintaining control over structure and function, and transcend to a post robust state of operations, if possible, a more favorable one than that prior to the event, is known as SCRES. This gives an organization a competitive advantage
Geng et al. (2013)	When coping with an undesired interruption, the cluster supply chain network experiences compounding failure, but it can perform self-repair through adaptability, allowing it to quickly recover to a new stable state
Wieland et al. (2013)	It is a capability either a supply chain can adapt to change and maintain its original stable position or achieve a new stable situation
Berle et al. (2013)	The capability of the supply chain to handle a disturbance without suffering significantly from it affects the mission of the supply chain
Brandon-Jones et al. (2014)	A system's capacity to recover from disturbances and return to its initial state within a reasonable amount of time is known as SCRES. The capability of a supply chain to resume normal operations after being disrupted within a reasonable amount of time
Roberta Pereira et al. (2014)	The ability of the supply chain to react swiftly to unanticipated occurrences in order to bring operations back to their pre-event performance level or even to a higher and newer one

(continued)

Table 4.1 (continued)

Authors	Definitions of supply chain resilience
Tukamuhabwa (2015)	The adaptable capacity of a supply chain to foresee potential disturbances and/or respond to them, recover quickly and affordably, and move forward to a post-disruption state of operations—ideally, one that is better than the pre-disruption state. The capability to not just manage risk but also to deal with it more effectively and economically than rivals, giving oneself a competitive edge
Kim et al. (2015)	To tolerate potential node or arc level interruptions as a network-level attribute
Hohenstein et al. (2015)	Supply chain resilience is the ability of the supply chain to be ready for unforeseen risk events, to respond and recover quickly to potential disruptions in order to return to its original situation or to grow by moving to a new, more desirable state in order to increase customer service, market share, and financial performance
Eltantawy (2016)	SC resilience is a meta-capability that enables the buyer's business to both quickly recover from disruptions and sustain performance goals over an extended length of time, as well as to ambidextrously resist damage and achieve a variety of potentially conflicting performance outcomes
Elleuch et al. (2016)	After being disrupted, a system's resilience is its capability to revert to its initial state or a more favorable one
Kamalahmadi et al. (2016)	The ability of a supply chain to adapt in order to decrease the likelihood of encountering unexpected disruptions, thwart the spread of disruptions by maintaining control over structures and functions, and recover and respond with quick and efficient reactive plans to get past the disruption and return the supply chain to a stable state of operation
Birkie (2016)	The potential of an organization to foresee, adapt, and continue operating in the face of interruptions
Lee and Rha (2016)	Resilience is the capacity to reframe previous experiences in order to secure a trustworthy SC Flexibility, visibility, cooperation, and security to speed up SC resilience
Brusset and Teller (2017)	Resilience is the ability of an organization or social body to recover after being significantly damaged by an exogenous attack. It is a key concept in sociology and ecology. A supply chain's capacity to revert to its initial condition of operation after being perturbed
Chowdhury and Quaddus (2017)	The ability of a system to absorb changes is described as resilience, which is a multidisciplinary notion. The idea of resilience is considered as a system's capacity to bounce back and revert to its initial form. Resilience can be defined in an organizational context as the ability of the organization to endure in a stressful environment

(continued)

Table 4.1 (continued)

Authors	Definitions of supply chain resilience
Ribeiro and Barbosa-Povoa 2018)	SC Resilience can be defined as the SC's capacity to tolerate steady-state changes and converge to either the initial state or a new desirable state. It was anticipated that the supply chain would recover, material flow and operating performance would resume, and disturbances would be resolved quickly
Junwei Wang et al. (2018)	A resilient system is one that aims to survive and continue operating even in the face of disruptions, is equipped with the ability to foresee potential disruptions and assess their potential damage, and is further strengthened by a keen awareness of its constantly changing environment and familiarity with past events
Jiang et al. (2019)	In the face of a disruption, a system's capacity to preserve and modify its fundamental structure and function is quickly outlined. Most often, resilience is described as a system's "ability" to withstand change and disturbance or as the "magnitude" of disturbance. Resilience is a means of reducing and containing the harmful effects of disasters
Jiang et al. (2021)	Supply chain resilience is to continuously sustain organizational development and be ready to act rapidly when the next crisis or disaster strikes, resilience is ingrained in a dynamic process. Planning, preparation, reaction, recovery, and resolution are the stages of the disaster management lifecycle that are associated to resilience
Ivanov (2021)	SCR refers to a company's capacity to endure, adjust to, and recover from disruptions in order to satisfy consumer demand, guarantee target performance, and continue operations in risky situations. Resilience is a measure of the supply chain's overall capacity to withstand damaging external interruptions and quickly resume normal operations
Ali et al. (2021)	The capacity of a company to recognize, accommodate, and promptly react to the changes brought on by an interruption in the supply chain. By predicting, preparing for, swiftly reacting to, and recovering more quickly from disturbances, enterprises can fulfill uncertain demand and gain a competitive advantage in the context of supply chain resilience (SCRes)
Kummer et al. (2022)	Resilience is a dynamic quality that emphasises an organization's capacity to acknowledge and adapt to change. As a result, robust parts (individuals, groups, and subsystems) are needed to create a resilient system. Being adaptive and capable of sustained reaction to unexpected and major shifts in the environment in the form of unclear demands, as well as the ability to maintain control over performance variability in the face of disturbance
Alzate et al. (2022)	Resilience is considered the capability to continue to achieve objectives despite disturbances and shocks
Ozanne et al. (2022)	Resilience has been defined as the capacity to build preventive capacity to deal with unforeseen disruptions while also taking the necessary and prompt actions to respond and recover to ensure company continuity

(continued)

Table 4.1 (continued)

Authors	Definitions of supply chain resilience
Kähkönen (2023)	Ability of a system to withstand disruption and yet carry out its fundamental duties. The capacity to react to and bounce back from unexpected interruptions like terrorism and natural disasters
El Baz et al. (2023)	The ability of a SC to resume normal operational performance after being disrupted is known as SCRE, which stands for the capability to anticipate and overcome disruption effect
Chang and Jiang (2023)	The notion of resilience and the sustainability of a system under uncertainty are comparable. a system's propensity to sustain its organizational structure and output in the face of disruption
Stentoft et al. (2023)	Supply chain resilience (SCR) is the ability of a corporation to "prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function"

4.2.2 Types of Supply Chain Resilience Strategies

Two types of SCRes strategies found in the literature are; proactive strategies and reactive strategies. Both cope with the "turbulence" in supply chains and sustain performance. Proactive strategies might include; appropriate supplier selection, building logistics capabilities, building security, building social capital, relational competencies, creating public–private partnerships, creating risk management culture, increasing innovativeness, increasing visibility, supply chain collaboration, supply chain network structure, sustainability compliance, use of information technology, and routing (Kummer et al. 2022). In addition, proactive strategy means that the supply chain is ready for both anticipated and unforeseen disruptions prior and during the disruption stage. Consequently, it is useful to establish proactive contingency plans to be able to fully comprehend the effects of disturbances and their possibility. On the other hand, reactive strategies focuses mainly on response and recovery post disruption given the resource and time constraints to obtain the benefits of these strategies. Reactive strategies are mainly about building logistics capabilities, building social capital and relational competences, contingency planning, creating redundancy, demand management, ensuring supply chain agility, increasing flexibility, increasing velocity, Increasing visibility, supply chain collaboration and use of information technology (Chowdhury and Quaddus 2017).

4.2.2.1 Proactive Strategy

In this section, a brief overview of the proactive strategies found in the literature is presented. Five main strategies are outlined due to their importance and relevance in the literature. The five strategies include supplier selection, building relationships, increasing innovativeness, network structure and design as well as production and process design. Each proactive strategy is explained briefly below.

Supplier Selection

Appropriate supplier selection is one of the major proactive resilience strategies focusing on utilizing selection factors, (such as quality, technological capabilities, financial stability, business continuity, reliability… etc.), which assist in reducing disruptions and their effects (Mascaritolo and Holcomb 2008). Therefore, Ribeiro and Barbosa-Povoa (2018) discuss the activity of picking suppliers while taking into account 13 traits important for appropriate supplier selection, which is organized into four groups of components (Primary performance factors, Supplier responsiveness, Supplier risk reduction, Supplier technical support, and Supplier sustainability based on Grey theory). In addition, building logistics capabilities supports in managing supply and information flows, such as risk hedging capabilities, information technology improvements, and information exchange, which are important to minimize vulnerabilities (Ponomarov and Holcomb 2009). Thus, sourcing strategy and

inventory management give added value. Furthermore, sourcing strategy and inventory management enhance resilience through multiple sourcing, back-up suppliers, supplier segmentation, perfect supplier allocation between limited resources and localized sourcing. The latter tends to procure supplies within the country it is located in allowing for control and a shorter lead-time of materials and quicker communication with the supplier as they are in the same country (Ivanov 2021).

Building Relationships

Building social capital and relational competences refers to effective pre-event communication and information exchange, which raises risk awareness and reduces susceptibility. For example relational competences could be enhanced through cooperation, trust, reciprocity… etc. (Johnson et al. 2011). Furthermore, coopetition - defined as establishing and maintaining cooperation amongst rivals to benefit from synergies, such as combining resources to develop security and resilience (Borekci et al. 2014)—is another approach to build social capital. Moreover, creating appropriate contractual agreements refers to contracts with long and short terms that provide for supply flexibility to reduce shortages (Tang 2006). In addition, creating public–private partnerships—public agency and private sector organization enter into a contract to share resources, risks, and rewards- in order to provide ideal services or facilities to the general public, which raises the government's interest in the supply networks of private companies (Stewart et al. 2009). Basically, creating risk management culture through ensuring that all organization members support supply chain risk management, which includes, for example, firm integration and teamwork (Christopher and Peck 2004).

Increasing Innovativeness

Ideally, increasing innovativeness is the desire and capacity to look for and develop new business concepts, such as new goods, services, technology, procedures, and tactics that can lessen vulnerability (Golgeci and Ponomarov 2013). In this sense, Glickman and White (2006) stated that increasing visibility is the capacity to observe all nodes and links in the supply chain, which aids in identifying potential threats. Similarly, knowledge Management which refers to gaining knowledge and comprehension of supply chain systems (physical and informational), as well as the capacity to teach other organizations and learn from changes (Rice and Caniato 2003). Additionally, building security through taking precautions against intentional disruptions of the supply chain, such as theft, terrorism, and the introduction of fake goods (Pettit 2008). Moreover, Urciuoli et al. (2014) stated that portfolio diversification is a consumption of a variety of goods to lessen reliance on specific goods and suppliers, While supplier development is providing incentives to suppliers, such as financial, training, and technical know-how, in order to increase productivity, commitment, and dependability. Basically, supply chain collaboration is the capacity to collaborate with other supply chain participants in a way that benefits both parties through exchanging knowledge and other resources to lessen vulnerability (Leat and Revoredo-Giha 2013).

Network Structure and Design

Scholten et al. (2014) define supply chain network structure/ design as the building of a resilient supply chain network by balancing factors such as redundancy, efficiency, vulnerabilities…. etc. Consequently, sustainability compliance is the reduction of chain risks such as reputational hazards, compliance with economic, social and necessary environmental criteria. Additionally, Soni and Jain (2011) approved that the use of information technology in terms of improving connectivity and promoting other resilience techniques, such as visibility and collaboration, which can aid in alerting users to potential disruptions. At the same time, these strategies should ensure both value added, cost efficiency and resilience achievement.

Production and Process Design

Production strategy and process design is through repurposing which refers to a firm's rapid conversion of capacities and capabilities to produce new-to-the-firm products in addition sub-contracting facilities, utilization of idle capacity, manufacturing, postponement, and automated factory (Ho et al. 2022). Also, Ivanov (2021) supported the use of transportation, distribution, network design and routing which achieves value added and resilience through multimodal and multi route shipments, back-up warehouse, emergency distribution planning and use of omni channels. The development of omni channels excels in this region by offering integrated data collection throughout all of its channels. Thus, forecasting gets more productive, and the brand benefits from its deployment hence, it acts as one-touch integration across all channels to ensure flexibility and efficient online and offline sales (Hansda 2021). Additionally, product line flexibility and modularization which means that food processors may be able to add, remove, or alter hardware from a production line using a modular approach with little to no downtime. Processes in the food manufacturing sector must be dependable, repeatable, error-free, and able to quickly ramp up production as needed (Aditi and Bharti 2021). In addition to inventory management which is known as a system-wide alignment of inventory management with the purpose of reducing inventory risks (Boone et al. 2013).

4.2.2.2 Reactive Strategies

As for the reactive strategies, building logistics capabilities dealing with instant flow of supply and information capabilities, such as those related to shorten cycle times, improve delivery competence, manage knowledge, and provide excellent customer service, can help an organization quickly recover from a disruption. In this sense, building social capital and relational competences refer to rapid access to the resources required for recovery which could be made possible through effective communication, trust, information sharing, collaboration, reciprocity, etc. after disruption (Tukamuhabwa et al. 2015). Moreover, contingency planning is identified as the steps taken to address supply chain risks and interruptions, and monitoring early warning signals. In addition, demand management is defined as influencing client

decisions through methods like dynamic pricing, assortment planning, and silent product rollovers, which might help to lessen the effects of interruptions. Furthermore, ensuring supply chain agility is the strategy to react speedily to erratic shifts in supply or demand (Urciuoli et al. 2014).

Increasing Capacity, Visibility and Velocity

Creating redundancy strategies necessitates acquiring spare capacity and inventory wisely and strategically. Redundancy strategies could be achieved by integrating supplementary facilities, extra suppliers, and spare stockpiles, in order to deal with disruptions. Thus, increasing flexibility is another strategy to test the capacity of a company's supply chain as whether it is quickly and easily adjusted to new requirements. Furthermore, increasing velocity—done through the speed of flexible modifications- can affect how quickly the supply chain recovers from an interruption (Longo and Oren 2008). Another reactive strategy is increasing visibility to view the whole supply chain, including all nodes and links, in order to react to a disruption quickly (Carvalho et al. 2012b). In addition, supply chain collaboration is the capacity to collaborate with other supply chain participants profitably, for example, by sharing knowledge and other resources required for response and recovery (Scholten et al. 2014). Finally, use of information technology improves connectivity and supports additional resilience methods, such as visibility and collaboration, which can aid in organizing responses to disturbances (Erol et al. 2010).

4.3 Supply Chain Resilience Measures

SCRes empirically tested research is difficult and controversial because of its multi-dimensionality and multi-disciplinary nature. Thus, it is stated by Ponomarov (2012) that SCRes is measured through supply chain resilience performance measurement items such as customer service level, forecasting, order fill and fulfillment rates, lead time ratio, shipment delay time and cost of backorder. In addition, it could be measured conceptually through measuring flexibility items such as flexible production, volume product variety/customization, multi-skilled workforce, contract flexibility, sourcing and distribution flexibility, redundancy, disruption occurrences, robustness, ability and capability to bounce back, financial strength, market position and recovery in addition to fault tolerance. Moreover, back up capacity, buffer stock, back up energy and utility source, preparedness and learning are measures of capacity alterations. Furthermore, Chowdhury and Quaddus (2017) measured SCRes in terms of ability to maintain situational awareness, ability to cope with the changes of disruption and ability to quickly respond to supply chain disruption. Ozanne et al. (2022) divided SCRes measurements into three items or phases readiness, response and recovery. Additionally, SCRes are aslo measured through quick restoration of product flow, coming back to original state after being disrupted, more desirable state after being disrupted, well- prepared for financial outcome of the disruption,

connectedness among partners of supply chain during disruption, as well as extraction of useful knowledge and learning from disruptions (Ponomarov 2012). Ribeiro and Barbosa-Povoa (2018) measured SCRes in terms of supply reliability, sustainability, visibility, agility, collaboration and recovery. The measures are dispersed and undefined. In conclusion, there is no consensus on which measures lead to which performance outcomes. Which leads to the next chapter on how SCRes is measured in relationship to performance outcomes.

4.3.1 Approaches Used in Supply Chain Resilience

In an attempt to find a relationship between SCRes and SC/Organizational performance, many authors have based their assumptions on theoretical underpinnings. These theoretical bases are numerous and confusing to the novel researcher. A list of theories adopted by the literature is presented in Table 4.2.

The dynamic capability theory has had a great influence on the research on SCRes. Hence, this theory would be further investigated in relationship to SCRes.

4.4 The Relationship Between Supply Chain Resilience and Supply Chain Performance Based on the Dynamic Capability Theory

According to Ponomarov (2012), the following capabilities are vital to organizations in a dynamic perspective: environmental uncertainty (EU) is proven to be positively correlated with supply chain vulnerability (SCV), supply chain resilience (SCRes) is positively correlated with supply chain capital, and supply chain knowledge development (SCKD) is positively correlated with SCRes. Furthermore, the resilience and continuity of corporate operations depend on the efficient management of supply and information flows. In addition, the significance of logistical capabilities as a priceless strategic resources is emphasized, building on earlier studies in the field. Lee and Rha (2016) intended to limit the negative effects of SC disruptions and enhance company performance by empirically exploring how organizations' SC ambidexterity is developed through a dynamic capability-building process. In this sense, it is discovered that addressing SC disruptions depends heavily on the organization's capacity to make the most use of already available resources and develop fresh solutions for issues and opportunities along the SC. Thus, SCRes is driven by SC ambidexterity. Additionally, the study supported the notion that SC ambidexterity enhances firm performance and investigates the critical function of supply management (SM) resilience skills in obtaining an ambidextrous state. Ambidextrous state is the state of attaining dexterous exploitation (making use of available resources and present competitive advantages) and exploration (find new resources and open up new markets) or high levels of

Table 4.2 Theories used in SCRes literature

Authors	Theories/approaches of resilience
Chowdhury et al. (2019), Johnson and Elliott (2011), Prasad et al. (2015), Polyviou et al. (2020), Herbane (2018)	Social capital theory and organizational resilience
Doerfel et al. (2013)	Social capital theory; evolutionary theory
Jia et al. (2020), Koronis and Ponis (2018), Duchek et al. (2020), Duchek et al. (2020), Sullivan-Taylor and Branicki (2011)	Organizational resilience
Martinelli et al. (2018)	Dynamic capabilities DC; Social capital theory
Mzid et al. (2019)	Sustainable family business theory
Other Bhaskara and Filimonau (2021)	Organizational learning theory; organizational resilience
Akpan et al. (2021), Battisti and Deakins (2017), Jiang et al. (2021), Kahkonen et al. (2021), Chowdhury and Quaddus (2017), Ivanov (2021), Kummer et al. (2022), Lee and Rha (2016), Ozanne et al. (2022), Jiang et al. (2021), Brusset and Teller (2017), Eltantawy (2016), Stentoft et al. (2023), Alzate et al. (2022), Ponomarov and Holcomb (2009), Ponomarov (2012), Yao and Meurier (2012), Golgeci and Ponomarov (2013), Schepers et al. (2021)	Dynamic capabilities DC
Ambulkar et al. (2015)	Resource reconfiguration; Supply chain disruption
Ates and Bititci (2011)	Organizational resilience; Change management
Craighead et al. (2007)	Supply chain structure
Cunha and Cunha (2006)	Complexity theory
Ismail et al. (2011)	Operational agility
Jiang et al. (2019)	Resource-based view RBV; DC
Limnios et al. (2014)	Socio-ecological systems theory
Manfield and Newey (2018)	Organizational resilience; DC
Martinelli et al. (2018)	DC; Social capital theory
Parker and Ameen (2018)	Organizational resilience; RBV; DC
Sabahi and Parast (2020)	RBV; DC
Ponomarov (2012)	DC and RBV
Kähkönen et al. (2023)	DC and RBV
Ali et al. (2021)	RBV and contingency theory (CT)

(continued)

Table 4.2 (continued)

Authors	Theories/approaches of resilience
Ribeiro and Barbosa-Povoa (2018)	Grey theory and DC
Tukamuhabwa et al. (2015)	Complex adaptive system (CAS)
Akpan et al. (2021)	DC
Ponomarov and Holcomb (2009), Blackhurst et al. (2011), Park (2011), Ponomarov (2012), Yao and Meurier (2012), Brandon-Jones et al. (2014)	RBV
Erol et al. (2010), Blackhurst et al. (2011), Spiegler et al. (2012)	Systems theory
Allen et al. (2006), Erol et al. (2010)	Complex systems
Day (2014)	CAS
Park (2011), Brandon-Jones et al. (2014)	Contingency theory
Wieland and Wallenburg (2013)	Relational view
Johnson et al. (2013)	Social capital
Urciuoli et al. (2014)	Rational choice theory

both. It was proposed that, in order to ensure the sustainability of the company, proper trade-offs between economic, environmental, and social results are required. The literature already in existence emphasizes how difficult it is to make successful trade-offs because of potential conflicts between disparate demands, such as conflicts between exploitative and explorative performance goals (Eltantawy 2016).

Chowdhury and Quaddus (2017) confirmed that the SCRes scale complies with the "technical" and "evolutionary" fitness criteria of dynamic capability theory and may be better at predicting supply chain operational vulnerability (OV) and supply chain performance (SCP). According to their research, supply chain managers should adopt proactive strategies for resilience, create a supply chain with fewer vulnerabilities, and enhance their reactive capabilities to quickly respond to weaknesses. In addition, it is confirmed that SCRes is a key success element for SCP development. In that matter, companies wishing to boost their performance must continually evaluate the effectiveness of the supply chain design as well as the proactive and reactive strategies used to address supply chain vulnerability. Consequently, it is significantly confirmed through their study that SCRes has a positive influence on SCP. In addition, Ivanov (2021) established that it is difficult to deploy resilience assets in a timely manner. Ivanov justified this claim by stating that the resilience theory does not provide any pointers to fill in this application-specific knowledge gap. Ivanov's study generated a fresh strategy to give the idea of SCRes more dynamics and consequently developed the AURA framework (Active Usage of Resilience Assets). The two main benefits of AURA are as follows: (1) Reducing the amount of work required to foresee disruptions; and (2) generating profit from resilience assets. In this sense, resilience is a natural, active, and value-creating element of operations management decisions as

opposed to a passive "shield" to guard against uncommon, serious catastrophes. Also, the increase of productivity and effectiveness is done by transforming resilience from a passive, cost-consuming asset into a paradigm for participatory decision-making.

Ali et al. (2021) intended to offer recommendations on how small and medium enterprises (SMEs) may respond, change, and adapt SCRes' reactive techniques to handle the disruptions caused by COVID19. Thus, the main goal of Ali et al's review is to give SCRes a clearer context in which companies could design reactive tactics that are compatible with the time and resource restrictions necessary to reap the rewards of these strategies. Depending on the supply chain context, disruption, and new environment, different resilience techniques may be employed by businesses. From the finding of this study it is proven that although it is true that intra-supply chain rivalry presently predominates over intra-firm competition, SCRes rely more on the strategic actions of a few major actors than it does on the complete transformation of the supply chain. In particular, this assessment highlights how crucial it is for businesses to be able to proactively react to and manage unforeseen events that occur at every level of the supply chain. Changes in food demand are anticipated, and these changes are typically an increase, to use the COVID-19 disruption as an example. To fit the disrupted environment, business resources must be reconfigured, realigned, and reorganized, and this must be addressed in the strategy. Ozanne et al. (2022) stated that for businesses to benefit from SC's resilience features, they must have three types of skills. The three skills are the ability to sense (i.e., the capacity to notice changes brought on by disruptions), the ability to seize (i.e., the capacity to create solutions for the changes), and the ability to reconfigure (i.e., the capacity to adapt continuously to changes).

According to Kähkönen et al. (2023), the effects COVID-19 had on a firm's upstream supply chain influenced the ability of the firm to take advantage of opportunities or counteract threats. In addition, configurability has proven to have a significant impact on supply chain resilience. While downstream disruptions took advantage of reconfiguration capabilities, upstream disruptions forced businesses to respond to risks and opportunities in the supply market. Therefore, assessing how COVID19 affected the strengthening of SCRes and the development of capabilities in the medical device sector by showing that the basic logic of DCV works in the case of disruptive events, during which companies try to reconfigure their operations to survive. It is shown that firms' capabilities to sense will affect their capabilities to seize, which will in turn affect their abilities to reconfigure. The fundamental premises of DCV hold true in the context of disruptive events, during which businesses attempt to restructure their operations in order to survive and it is demonstrated that how a firm's capacity to sense will influence its capacity to grasp, which will influence its capacity to reconfigure.

Jiang et al. (2021) mentioned that there are various options for SMEs to use SC to increase their resilience, illustrated by their middle-range theorizing. In conclusion, the objectives of their study was to investigate organizational responses to disasters through their deployment of dynamic capabilities and resources and build a unique processual dynamic resilience framework representing a capability-based process at various disaster management phases. Examining the impact of COVID-19 on firms'

dynamic capabilities (sensing, seizing, and reconfiguring). The study then further examined the influence of those impacts on SCRes. Impacts on upstream firms did not influence sensing or reconfiguring capability, but did influence firms' ability to seize opportunities or neutralize threats.

4.5 Research Gaps

From the above literature, it is deduced that there are many gaps within the academic studies of SCRes. Gaps related to the definitions and measures of SCRes capabilities in general and the applications of the dynamic capability theory in particular.

4.5.1 Gaps Related to Supply Chain Resilience

There is vagueness in the conceptual definition of SCRes. There is no consensus on the correct definition for construct development. The construct is widely used in a very elusive context. The words supply chain resilience, supply chain robustness; supply chain agility and supply chain risk management are frequently used interchangeably. The antecedents and consequences of each of the above-mentioned constructs are intertwined (Ponomarov 2012). Furthermore, the measurement items of each of the above constructs including the construct SCRes is not defined vigorously in the literature. There is no methodological approach to identify which measures should be used in a specific context. Both supply chain proactive and reactive resilience strategy items need to be operationalized further.

Theoretically, there is no differentiation between resources, strategies and capabilities in a SCRes context. The literature does not differentiate between which types of resources are needed to generate SCRes in both proactive and reactive strategies. Correspondingly, most research employ the essence of Teece's dynamic capability framework without distinctive clarification of the phases of the dynamic capability theory (sensing, seizing and transform) (Chowdhury and Quaddus 2017). Most of the previous studies conducted on specific context, industry and culture, which might affect generalizability. Cross-sectional research approach is only used which is limited to a point-in-time assessment. Thus, the long-term effects of SCRes on supply chain performance may be captured more effectively through a longitudinal research approach. Therefore, a longitudinal focus is advised for future research.

Existing debates and gaps in the literature necessitate the conceptualization and empirical investigation of SCRes measurement constructs because there isn't a simple definition of SC silience that can be applied to a variety of situations. At this point in the research, more advancements are needed to consolidate the existing SC resilience definitions. Since there hasn't been much quantitative study "assessing and measuring" SCRes, most studies in the resilience field have been qualitative. This has had an

impact on empirical studies in this field. In addition, the connection between agile, robust and resilient supply chain should be clarified.

There is still no comparison analysis to ascertain how a pandemic affects various industries and nations, therefore the study on its effects is still in its early stages. In the future, emphasizing the lessons learnt will be crucial for better preparing businesses for situations that could be disastrous. Although many of the studies applied dynamic capability theory still there is no clear SCRes given dynamic capabilities framework to be used as a guide for firms for situations that could be disastrous in terms of distinguishing between capabilities and resources. The dynamic capability theory has been criticized for its lack of "empirical grounding (Kähkönen et al. 2021). Literature is still at the stage of conceptualization, especially in the context of the food supply chain and SMEs. SCRes has been decomposed into four different phases, i.e., readiness, response, recovery, and growth, and two types of strategies, i.e., proactive strategy and reactive strategy. Future research should examine other phases and strategies (Ali et al. 2021).

4.5.2 Future Implications

Future study may focus on including additional aspects of supply chain management, such as resilience and sustainable value creation. Additionally, the paradigm can be expanded by include the prices and quality dimensions related to various resilience capabilities (Ivanov 2021). Investigating the sequential impact of ambidexterity as a dynamic capability using time-series data is important for future research. Even though the definition of ambidexterity is clear, measuring it in terms of exploitation and exploration is not easy, as ambidexterity relies on various conceptualizations (Lee and Rha 2016).

The combination of various operations research techniques should also be investigated, since, for example, the use of decision analysis techniques in conjunction with optimization would make it possible to convert the qualitative ideas that are frequently present in SC resilience issues into quantitative forms that can be addressed by optimization (Ribeiro and Barbosa-Povoa 2018). Due to their limited resources and capabilities, SMEs and large companies may have differing resilience capability profiles. Within these two contexts, there is a need to comprehend and contrast the SCRes capacities. Further investigation of the interaction between slack resources and DCs may be necessary to understand the mechanism. Which DCs, for instance, can (re)configure slack resources for various recovery goals, what type and quantity of slack resources can launch DCs, as well as what potential effects might organizational demographics—like sectors, firm size, and age—have on those decisions have. The limitations that may prevent the growth of DCs could be further investigated to determine why some organizations are unable to respond to crises or disasters. These limitations may be brought on by a lack of knowledge, managers' restricted rationality, a misunderstanding of feedback, or even a lack of holistic thinking. This incapacity might be explained by the notion of path dependence or organizational

inertia (success trap), which takes into account how organizations' learning activities and strategies can be constrained by their prior experience and prior choices in dynamic contexts (Jiang et al. 2019).

4.5.3 Conclusion

In this study, a comprehensive literature review was conducted to highlight the main definitions, measures, strategies and theoretical basis used in the supply chain literature. A historical overview of the definitions of SCRes is presented. A holistic combination of most of the measures used to quantify SCRes is proposed. The difference between both proactive and reactive strategies is described. The theoretical models used to base key relationships in SCRes towards supply chain performance are outlined. The dynamic capability theory is described in the SCRes context. Studies investigating SCRes under the theoretical aspect of the dynamic capability theory are explained. Major gaps due to this literature review are provided and future implications necessary to fill in these gaps are proposed.

4.5.4 Insights and Implications Post COVID Practice

In light of the above-mentioned definitions, the author concludes that resilience in a post COVID era should be defined as "The cost effective adaptive capabilities, required to maximize the speed of recovery to pre COVID regular levels of performance, desired state of performance or value added performance. This is achieved by applying both proactive and reactive SCRes strategies to maintain control over structures and functions post COVID.

In reference to the measures and the dynamic capability theory, resilience measures should be divided to the three phases of the dynamic capability theory sensing, seizing and transforming. Figure 4.1 summarizes the output of this analysis:

The above framework should be used in future studies to address the gap in both the theoretical and measurement aspect of SCRes. Authors could employ the above framework to find relationships between sensing, seizing and transforming capability in alignment with the dynamic capability theory. Additionally, authors should exert efforts to understand the difference between resources and capabilities in a SCRes context. Which resources are required to sense, seize and transform would be an adequate research question for further exploration. In conclusion this study has highlighted many gaps in an attempt to shed some light on future implications in the field of SCRes.

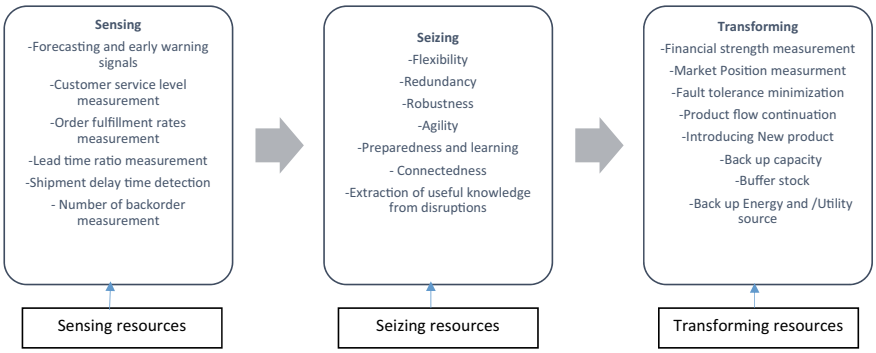

Fig. 4.1 Sensing, seizing and transforming capabilities adopted from Chowdhury and Quaddus 2017; Pourhejazy et al. 2017; Lee and Rha 2016

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Chapter 5
Principal Lessons Learned from COVID-19: Prescriptive and Long-Lasting Strategies for Sustainable Supply Chain Improvement

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Abstract COVID-19 has unprecedentedly disrupted global supply chain operations, highlighting previously overlooked weaknesses and inefficiencies. This theoretical paper examines the lessons learned from the pandemic and proposes a long-lasting approach to address current supply chain shortcomings. We draw on supply chain theory insights to identify key pandemic-related challenges, including insufficient visibility into supplier and customer networks, critical supply and component shortages, and the necessity for agile and resilient supply chain operations. This paper suggests several prescriptive recommendations to address these challenges, including the use of machine learning and data analytics to enhance supply chain visibility and forecasting, the creation of more robust contingency plans and risk management tactics, and the execution of cutting-edge technologies like AI, BT and IoT to boost supply chain traceability and transparency. The prescriptive approach extracted from contemporary literature encompasses a long-term roadmap to transform supply chain operations to become more sustainable, responsive, and resilient. This roadmap includes integrating supply chain functions with other business processes and adopting new business models prioritizing collaboration, flexibility, and innovation. The extensive literature review highlighted twenty supply chain bottlenecks and possible solutions to keep the supply chain upright and sustainable, which can handle uneven shocks like pandemics, natural disasters, etc. Several instances are also discussed to validate the effectiveness of possible recommendations for the existing supply chains. The proposed prescriptive approach includes enhanced supply chain performance, reduced risk and cost, and improved customer satisfaction. We argue that the lessons erudite from the pandemic present a unique

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opportunity for supply chain experts to reconsider and transform their operations to address the challenges of a complex and uncertain global business environment.

Keywords Supply chain · Sustainability · COVID-19 · Pandemic · Operations · Supply chain operations · Logistics and transportation · Supply chain visibility · Supply chain flexibility and agility · Single-source suppliers · Reliable backup plans · Supply chain agility · Predictive analytics · Supply chain bottlenecks · Lack of flexibility and visibility

5.1 Introduction

Global supply networks have been cruelly interrupted due to the COVID-19 epidemic. The virus has impacted every supply chain step from acquiring raw materials to production to logistics and distribution. The pandemic has uncovered the weaknesses of worldwide supply chains and the risks associated with depending on only a few critical suppliers. The lack of raw materials posed a significant supply chain problem during the pandemic. Production delays and decreased output were caused by a lack of inventory brought on by the shutdown of facilities and warehouses. The electronics, automobile, and medical device industries were all impacted by this. Disruptions in logistics and transportation were another issue the supply chain had to deal with. Due to delays in shipping and delivery caused by border closures and travel restrictions, there was a shortage of essential goods and items. A lack of warehouse and truck drivers also hampered the timely delivery of goods. The epidemic also highlighted the fragility of supply chains. Businesses widely used just-in-time inventory management; therefore, they maintained little stock on hand. Because they could not react quickly to changes in demand, they were vulnerable to unforeseen supply chain disruptions.

The pandemic has brought to light long-standing flaws and inefficiencies in global supply systems that had gone unreported. Supply chain expertise faces unprecedented difficulties due to the epidemic, including disruptions in supplier and customer networks and shortages of essential supplies and components. Supply chains play a decisive role in the global economy, facilitating the transportation of products and services from where they are made to where they are needed. The pandemic has brought a multitude of challenges for global supply chains. A Variety of factors, including restrictions on travel and government-mandated shutdowns and labor shortages resulting from illness or quarantine, have disrupted the smooth and continuous flow of the supply chain. These factors have created difficulty in transporting goods and raw materials and caused production delays, leading to shortages of critical supplies. Inventory management has become increasingly challenging, with supply and demand disruptions leading to excess inventory, stockouts and higher materials costs. The pandemic has exposed the shortcomings of current supply chain operations, such as the lack of flexibility and visibility, over-reliance on single-source suppliers, and inadequate contingency planning. Also, the pandemic has revealed the

lack of communication and collaboration between supply chain partners, leading to further disruptions in supply chain operations. These disruptions have underlined the importance of resilient supply chains that adapt quickly to unforeseen circumstances.

The broken supply chain has severely impacted businesses and consumers alike. Businesses have faced significant financial losses due to delayed production and distribution, while consumers have experienced shortages and increased prices for essential goods. Covid conveyed a big lesson to all victim companies: diversify their supply chains, invest in digital technologies to improve efficiency and visibility and adopt more sustainable and ethical practices. Despite the significant influence of the pandemic on supply chains, there are opportunities to enhance supply chain flexibility and agility. For example, some companies have used technology to track the movement of goods, enabling better visibility and control over their supply chains. Additionally, companies have looked for alternative suppliers and diversified their supply chains to reduce reliance on single-source suppliers. However, there is still a need to develop further resilient and adaptive supply chains.

This research study examines how the pandemic has revealed the inadequacies of current supply chain practices and what lessons can be learned from it. The study aims to provide a long-term prescriptive offering for addressing the failures of current supply chain operations and developing more robust and responsive supply chains. This study offers a long-term prescriptive approach to resolving current supply chain flaws in response to these difficulties, building on the pandemic lessons learned. In order to increase supply chain traceability and transparency, this literature review research also drew some prescriptive recommendations for strengthening supply chain visibility, creating more reliable backup plans, and using new technology. The prescriptive strategy also incorporates a long-term roadmap for refining compliance and ensuring sustainable practices.

5.2 Objectives and Methodology

The main aim of this research study is to recognize the insights obtained from the COVID-19 pandemic that revealed the deficiencies in the current supply chain operations. Later, the study aims to provide a long-term prescriptive offering to address the limitations of current supply chain operations and develop more robust and responsive supply chains. The research will focus on supply chain agility, visibility, transparency, diversification, technology and collaboration as critical areas for enhancing resilience and adaptability. This study utilizes literature review methods, including a comprehensive literature review and qualitative interviews with supply chain experts to validate certain statements. The study conducted qualitative interviews with supply chain experts from different industries to gain insights into the specific challenges supply chains face in responding to the pandemic. The discussions will look at the tactics used by supply chain practitioners to lessen the pandemic effects and pinpoint best practices for creating more robust and long-lasting supply chain operations.

5.3 Identifying Supply Chain Bottlenecks and Possible Solutions

Identifying supply chain bottlenecks is crucial for companies looking to optimize their operations and improve efficiency. Secondary research articles can provide valuable insights into the common types of bottlenecks that companies face, such as transportation delays, labor shortages, inventory shortages, and production constraints. These articles can be analyzed to help businesses comprehend bottlenecks underlying causes and create solutions. Such a review helps to identify emerging trends and technologies that may help alleviate supply chain bottlenecks, such as predictive analytics, automation, and blockchain technology. The main supply chain bottlenecks during the pandemic are listed in Table 5.1 along with possible solutions taken from the literature.

Thousands of diverse problems arise during the pandemic time with no immediate solutions. Later various research studies were conducted to ensure which are the leading causes and bottlenecks hit by the mist supply chain related businesses. COVID-19 has revealed a number of unavoidable issues in global supply networks, which are discussed below.

5.3.1 Demand and Supply Uncertainty

The pandemic has caused a high level of uncertainty in the global economy, leading to significant disruptions in demand and supply chains. The pandemic has caused considerable uncertainty in global supply chains, affecting both upstream and downstream suppliers (Butt 2021). These disruptions have led to the need for companies to invest in cutting-edge technologies to enhance their supply chain visibility and build resilience to future disturbances. Besides, post-COVID times are expected to see ongoing uncertainty in demand and supply chains, with some sectors experiencing sustained changes in consumer behavior in terms of demand (Sharma et al. 2022). As a result, companies must remain flexible and adaptive but vigilant to deal with supply–demand uncertainty to protect the disasters.

5.3.2 Material Shortage

The pandemic has resulted in significant raw material shortages in various industries, leading to disruptions in supply chains. The pandemic has triggered substantial disruption in global supply chains, leading to a shortage of raw materials, particularly those sourced from countries heavily impacted (Xu et al. 2020). This Shortage has been further compounded by increasing demand in certain industries, such as the healthcare sector, such as medical instruments and personal protective equipment

Table 5.1 Key supply chain bottlenecks and possible solutions

SL	Key supply chain bottlenecks	References	Possible solutions	References
1	Demand and supply uncertainty	Alkahtani et al. (2021 and Raj et al. (2022)	Improve the balance between demand and supply	Praharsi et al. (2021) and Magableh (2021)
2	Material shortage	Ivanov and Dolgui (2022) and Sheffi (2021)	Improve and invest in sustainability	Yi et al. (2022) and Trabucco and De Giovanni (2021)
3	Delayed in timely deliveries	Cai and Luo (2020) and Magableh (2021)	Develop a crisis management plan	Fonseca and Azevedo (2020) and Min (2023)
4	Lack of Visibility	Zhu et al. (2020)	Improve supply chain visibility	Ivanov (2021) and Yang et al. (2021)
5	Port congestion	Komaromi et al. (2022) and Bolat et al. (2020)	Enhance supply chain agility	Wang and Wang (2023) and Maemunah and Cuaca (2021)
6	Disruptive food supply chain	Davis et al. (2021) and Espitia et al. (2020)	Diversify supplier base	Javorcik (2020), Wang et al. (2023, and Remko (2020)
7	Shortage of personal protective equipment	Park et al. (2020)	Emphasize employee health and safety	Ambrogio et al. (2022) and Loker (2020)
8	Driver shortages	Costello and Suarez (2015) and Chandiran et al. (2023)	Employee-friendly HR policy	(Acquah et al. 2020; Aldaas et al. 2022)
9	Semiconductor shortage for the auto industry	Dunn and Leibovici (2021) Ramani et al. (2022)	Counter strategies on semiconductor shortage	Mohammad et al. (2022) and Ishak et al. (2022)
10	Russia-Ukraine War and risks to global supply chains	Trachova et al. (2022), Falkendal et al. (2021, and Jagtap et al. (2022)	Building future resilience based on the war situation	Dyson et al. (2023) and Jagtap et al. (2022)
11	Vaccine supply chain	Golan et al. (2021) and Georgiadis and Georgiadis (2021)	Efficient supply chain traceability	Rinaldi et al. (2022) and Finkenstadt and Handfield (2021)
12	Shortages of critical supplies and components	McKee and Stuckler (2020)	Implement a risk management strategy	Hohenstein (2022) and El Baz and Ruel (2021)
13	Lack of resilience	Golan et al. (2020) and Schleper et al. (2021)	Achieve supply chain resilience	Trabucco and De Giovanni (2021) and Mishra et al. (2022)
14	Lithium-ion battery crisis	Egbue and Long (2012) and Olivetti et al. (2017)	Improve transparency and collaboration through technology	Adhi Santharm and Ramanathan (2022) and Nandi et al. (2021)

(continued)

Table 5.1 (continued)

SL	Key supply chain bottlenecks	References	Possible solutions	References
15	Global shipping containers shortage	Yi (2022) and Aguilar-Mäkelä (2022)	Enhance supply chain visibility	Ivanov (2021), Alicke et al. (2021) and Shamsuddoha (2022)
16	Last-mile delivery challenges	(Srinivas and Marathe 2021)	Innovative solutions in last-mile delivery	Mohammad et al. (2023) and Argyropoulou et al. (2023)
17	Inadequate contingency planning	McDermott et al. (2021)	Develop robust contingency plans	Ash et al. (2022) and Das et al. 2021)
18	Lack of traceability and transparency	Rinaldi et al. (2022), difficult (DiMase et al. 2016)	Invest and adopt new technology	Trabucco and De Giovanni (2021), Remko (2020), Joshi and Sharma (2022), and Modgil et al. (2021)
19	Labor shortage	Biswas and Das (2020), Agrawal et al. (2020), and Okorie et al. (2020)	Ensuring available labor for normal operations	Nagurney (2021) and Pitschner (2022)
20	High freight and container handling cost	Perkumienė et al. (2021) and Barbosa et al. (2022)	Minimize freight and container handling costs	Tsai and Chang (2022) and Khan et al. (2022)

(Gereffi 2020). In post-COVID times, businesses must continue to monitor their raw material supply chains and explore alternative sources to mitigate future shortages. This requires building resilience and diversification into their supply chains to ensure a consistent raw materials supply even in crisis times.

5.3.3 Delayed in Timely Deliveries

When supply chains depend on regular and punctual deliveries, they become susceptible to disruptions that affect them on a large scale. With the pandemic spreading rapidly, the demand for medical equipment surpassed the supply, highlighting the vulnerability of such supply chains. Keeping additional inventory on hand may make the medical supply chain more adaptive in the event of another outbreak. This directly opposes the core concepts of Just-in-Time (JIT) planning (Zhu et al. 2020). In this situation, supply chain needs to find a balanced approach between JIT and traditional processes.

5.3.4 Lack of Visibility

One of the most significant problems highlighted by the pandemic is the lack of visibility into supplier and customer networks (Raj et al. 2022). Many businesses have complex supply chains that span many nations and continents, making it challenging to check inventory levels and anticipate disruptions. As a result, many companies suffered due to unexpected disruptions, resulting in shortages of crucial supplies and components.

5.3.5 Port Congestion

Rising prices and empty shelves have led many people to see the visible signs at local ports congested with shipping containers and ships idly sitting in the harbors (Bolat et al. 2020). These port congestions lead to long delays, resulting in longer delays in delivering goods to consumers and firms. The leading causes of port congestion include documentation procedures, port management, ship traffic, port structure and strategy, and government relations (Komaromi et al. 2022).

5.3.6 Disruptive Food/essentials Supply Chain

Davis et al. (2021) analyzed the effects of environmental variability on food supply chains primarily focused on maize, rice, and wheat production, extreme rainfall, and temperature. Due to the pandemic, farming has struggled with a lack of seasonal workers due to lockdowns and travel restrictions. The developed world has reacted better to these bottlenecks due to technological advancements (Deconinck et al. 2020). It is crucial to explore the food basket and prepare for possible disruptions.

5.3.7 Shortage of Personal Protective Equipment

Bottlenecks in PPE have developed due to a lack of inputs such as nonwoven polypropylene (used in facemasks), melt-down production lines (used to produce machines for facemasks), high concentration of manufacturers in one area (which made worker quarantines more damaging due to a lack of workers), export bans on facemasks (which made it harder for specific regions to import facemask from others), etc. (Park et al. 2020).

5.3.8 Driver Shortages

Truck driver shortage is not new (Costello and Suarez 2015) but intensified after COVID. Chandiran et al. (2023) examined the impact of supply chain disruptions on driver shortages in the transportation industry. The authors argue that supply chain disruptions can alleviate driver shortages by reducing the demand for transportation services. This bottleneck is difficult to overcome due to training, driver availability and compliance issues.

5.3.9 Semiconductor Shortage for the Automobile Industry

COVID-19 has impacted the auto industry regarding a shortage of semiconductors (Dunn and Leibovici 2021). This has impacted nearly all auto companies and 170 other industries, resulting in a loss of 110 billion in the auto industry alone (Ramani et al. 2022). The Covid and subsequent lockdowns in many nations were external shocks that led to the chips scarcity for the auto sector, whereas consumer and chip manufacturer reactions to the Shortage were internal shocks (Ramani et al. 2022).

5.3.10 Russia-Ukraine War and Risks to Global Supply Chains

The current conflict between Ukraine and Russia has cut off important shipping routes, forced transport companies to suspend service, and led to soaring air freight rates (Ngoc et al. 2022). For instance, the southern coast of Ukraine, including cities like Mariupol and Odesa, has been effectively sealed off due to shelling, completely cutting off locations like the Sea of Azov, while the risk of missile attacks from the ground and fighter jets in the air poses a threat to air transportation (Trachova et al. 2022). Ukraine serves as the breadbasket of Europe in terms of grain and both Ukraine and Russia are huge exporters of this agricultural commodity. Due to the war, production, sourcing, logistics, manufacturing, and grain processing have all been disrupted and put under threat (Falkendal et al. 2021). Due to the reliance of other countries on grain from Ukraine and Russia, demand shifts have occurred, and when coupled with the factors mentioned above, have led to spikes in food prices globally, as numerous food products contain grains (Jagtap et al. 2022).

5.3.11 Disruptive Vaccine Supply Chain

The supply chain is highly interconnected globally, meaning that even a minor delay or issue can impact the entire world (Georgiadis and Georgiadis 2021). Companies have struggled to produce enough vaccines to meet the high demand due to the difficulty of manufacturing them quickly (Georgiadis and Georgiadis 2021). Therefore, it is crucial to have a robust and efficient vaccine supply chain that can reliably produce and distribute vaccines to targeted populations despite unexpected problems or disruptions (Golan et al. 2021).

5.3.12 Shortages of Critical Supplies and Components

The pandemic has resulted in shortages, particularly in the healthcare industry. The pandemic has increased demand for critical medical supplies such as ventilators, masks, and testing kits, leading to shortages in many countries (Ranney et al. 2020). The Shortage of these critical supplies has been attributed to various factors, including supply chain disruptions, hoarding by countries, and inadequate production capacity.

5.3.13 Lack of Resilience

The pandemic has revealed the fragility of various supply chains, as many companies have prioritized maximizing their supply chain efficiency at the cost of resilience (Golan et al. 2020). As a result, when the pandemic emerged, several supply chains could not respond swiftly to the abrupt supply and demand fluctuations, causing production and delivery delays (Schleper et al. 2021).

5.3.14 Lithium-Ion Battery Crisis

The rising popularity of electric vehicles in the transportation industry has increased the demand for lithium batteries. While some of the materials required to make these batteries, such as manganese, nickel, and natural graphite, are readily available, others, like cobalt and lithium, are more challenging to obtain (Egbue and Long 2012). These materials are often located in politically unstable regions in Africa and South America, making it difficult to access them. This has resulted in significant bottlenecks, exacerbated by the considerable surge in demand for these materials in recent years (Olivetti et al. 2017).

5.3.15 Global Shipping Container Shortage

Transporting goods globally relies heavily on containers, which form a significant part of the world's supply chain. Unfortunately, the pandemic has threatened the container shipping industry (Yi 2022). The pandemic caused a surge in demand for various goods and services, putting immense pressure on the limited number of containers available for shipping. In 2020, the shutdown of activities in China resulted in port terminals and trucks stopping. This led to a backlog of cargo that needed to be transported in restricted containers (Aguilar-Mäkelä 2022).

5.3.16 Last-Mile Delivery Challenges

COVID-19 has brought to light the difficulties of last-mile delivery in the logistics industry (Srinivas and Marathe, 2021). The pandemic has led to a surge in e-commerce sales, increasing demand for last-mile delivery services and putting pressure on logistics providers to meet delivery deadlines (Srinivas and Marathe 2021). The challenges of last-mile delivery during the pandemic include disruptions in the supply chain, changes in consumer behavior, and new health and safety protocols (Suguna et al. 2021). With the growth of e-commerce, last-mile delivery challenges are expected to persist post-COVID, and logistics providers must invest in technology and innovation, adopt new delivery models, and build resilience in their supply chains to mitigate disruptions (Suguna et al. 2021). Governments and regulators may also need to consider new policies and incentives to support the last-mile delivery sector (Suguna et al. 2021).

5.3.17 Inadequate Contingency Planning

The pandemic showed that backup plans are crucial for the supply chain industry. Some companies were unprepared for the unexpected changes caused by the pandemic, which caused problems getting essential supplies and parts. As a result, it affected their ability to meet production deadlines (McDermott et al. 2021).

5.3.18 Lack of Traceability and Transparency

The pandemic has highlighted the lack of traceability and transparency in many supply chain operations (Rinaldi et al. 2022). Many companies have complex supply chains that involve multiple suppliers and subcontractors, making tracking the origin and movement of goods complex (DiMase et al. 2016). This lack of traceability

and transparency makes it hard to ensure that goods are produced and transported efficiently and timely.

5.3.19 Labor Shortage

The COVID-19 pandemic has led to labor shortages in many industries, particularly in hospitality, agriculture, and manufacturing (Khanna 2020). The pandemic has resulted in widespread job losses and reduced working hours, leading to many industries' shortages of skilled and unskilled workers. Factors contributing to the labor shortage include health and safety concerns, travel restrictions, and changes in consumer behavior. Post-COVID times likely see ongoing labor shortages as the global economy recovers from the pandemic.

5.3.20 High Freight and Container Handling Cost

COVID-19 has disrupted global supply chains, leading to high freight and container handling costs. The pandemic has increased shipping costs due to a shortage of containers and disruptions in global logistics networks (Notteboom et al. 2021). Post-COVID times are likely to see continued challenges in managing freight and container handling costs (Merk et al. 2022). To address these challenges, companies may need to explore new shipping routes, optimize supply chain networks, and invest in technology to streamline logistics operations. Also, policymakers may need to implement measures to support the transportation industry and address supply chain disruptions caused by the pandemic.

5.4 Recommendations from Contemporary Literature (2020–2023)

In addition to the abovementioned challenges, numerous other supply chain issues have arisen due to the pandemic, and all of them have been adversely affected by the supply chain industry. Based on concurrent literature, this study accumulates a set of prescriptive recommendations to address the above supply chain problems.

5.4.1 Improve Supply and Demand Imbalance

Companies must continuously monitor their supply chain operations and identify areas for improvement (Hohenstein 2022). This approach includes leveraging data analytics and performance metrics to drive continuous improvement and optimize supply chain operations. Focusing on continuous improvement is crucial to restoring supply and demand and overcoming the impact of Covid-19. Businesses can use data analytics to identify process bottlenecks, optimize production, and reduce waste and can adapt to changing market conditions, improve efficiency and productivity, and restore supply and demand to pre-pandemic levels, ensuring they remain competitive during and after the pandemic.

5.4.2 Improve and Invest in Sustainability

Companies must adopt sustainable practices (Shamsuddoha and Woodside 2023) across their supply chains, including reducing carbon footprint, minimizing waste, and adopting circular economy principles (Khan et al. 2021). This approach would help build more resilient and sustainable supply chains for the future. Investing in sustainability can help restore normal conditions, supply, and demand during and after the Covid-19 pandemic.

5.4.3 Develop a Crisis Management Plan

Companies must develop a crisis management plan to handle unforeseen events such as pandemics, natural disasters, or geopolitical risks (Sivaprasad and Mathew 2021). This plan should include clear communication protocols, alternative supply chain options, and a contingency budget. Creating a clear crisis management plan can help businesses reduce the impact of COVID-19 and other possible crises, ensuring that they stay operational and competitive both during and after the pandemic.

5.4.4 Improve Supply Chain Visibility

Companies should invest in tools and technologies that enable real-time visibility of their supply chain operations through RFID and cloud computing (Gammelgaard and Nowicka 2023). This approach would help identify potential disruptions and provide early warnings for corrective action. Also, IoT devices and data analytics, organizations can gain real-time insights into their supply chain, identify potential bottlenecks and disruptions, and optimize their operations (Kashem et al. 2023).

This enhances resilience and enables businesses to manage customer demand better, ensure business continuity, and mitigate the impact of Covid-19 on their bottom line.

5.4.5 Enhance Supply Chain Agility

To cope with COVID-19, companies need agile supply chains that can quickly respond to changes in demand and supply. Industry can do it using just-in-time inventory management, flexible manufacturing processes, and optimizing logistics and transportation (Wang and Wang 2023). Improving supply chain agility involves using different suppliers, investing in technology, and adopting lean principles. Such practice helps the business to respond better to changes in demand and supply, adapt to new customer needs, and reduce risks.

5.4.6 Diversify Supplier Base

Companies must diversify their supplier base to reduce dependency on one region or supplier (Remko 2020). This approach would help mitigate the impact of disruptions in a single region or supplier and maintain continuity of operations. Businesses can source food products from multiple suppliers to reduce the risk of supply chain disruptions and ensure continuity of operations. This can retain customer product availability during and after the pandemic while fostering a competitive environment that encourages suppliers to improve quality, cost, and delivery time.

5.4.7 Emphasize Employee Health and Safety

Companies must prioritize employee health and safety by implementing measures to protect workers from spreading disease (Ambrogio et al. 2022). This could include providing personal protective equipment (PPE), adopting social distancing protocols, and offering telecommuting options. Organizations should prioritize the health and safety of their employees by providing personal protective equipment, enforcing social distancing measures, and implementing regular cleaning and disinfection protocols.

5.4.8 Employee-Friendly HR Policy

Companies can mitigate the effects of COVID-19 by adopting employee-friendly HR policies that prioritize the well-being of their workforce. This can increase productivity and staff retention (Aldaas et al., 2022). Such policies include flexible work arrangements, mental health support, and paid sick leave. In the future, companies may need to update their HR policies to adapt to new challenges brought on by remote work and evolving employee expectations. Employee-friendly HR policies can also improve a company's reputation and attract high-quality talent.

5.4.9 Counter Strategies on Semiconductor Shortage

Companies can employ various strategies to combat the impact of the semiconductor shortage during and after COVID. One practical approach is diversifying their supplier base to avoid dependence on a single supplier or region (Mohammad et al. 2022). Another option is investing in research and development to develop alternative technologies or improve existing ones to reduce reliance on semiconductors (Ishak et al. 2022). Collaborating with suppliers, customers, and policymakers can help address the semiconductor shortage. Companies may need to optimize inventory management and production processes to maximize available semiconductors.

5.4.10 Building Future Resilience Based on the War Situation

To overcome the COVID and post-COVID impacts, companies can assess past war situations and build future resilience. This may include developing contingency plans, diversifying supply chains, investing in R&D, and improving communication and stakeholder collaboration (Dyson et al. 2023). Companies can also embrace innovation and technology to adapt to changing market conditions and consumer behaviors and prioritize employee well-being and engagement to maintain productivity and reduce turnover. Building resilience based on war situations can help companies prepare for unforeseen challenges and emerge stronger from the crisis.

5.4.11 Efficient Supply Chain Traceability

Efficient traceability and transparency can help companies overcome the impacts by improving supply chain resilience and reducing risks. Implementing innovative technologies like blockchain, IoT, and data analytics can improve the visibility and

accountability of the supply chain, thus achieving this objective (Rinaldi et al. 2022). Companies can anticipate disruptions, optimize inventory levels, and improve forecasting accuracy by enhancing supplier and customer network visibility. Likewise, efficient traceability and transparency can help companies build trust with customers and other stakeholders, which is critical for long-term business success.

5.4.12 Implement a Risk Management Strategy

Organizations should conduct a comprehensive risk assessment to identify potential threats and vulnerabilities to their operations, customers, employees, and supply chain. They should then develop and implement risk mitigation measures such as contingency plans, insurance, and diversification of supply chains (Hohenstein 2022). By regularly reviewing and updating their risk management strategy, businesses can improve their resilience and adaptability to changing market conditions, ensuring they are better equipped to navigate the impact of Covid-19 and other potential crises (El Baz and Ruel 2021). Companies must identify potential risks and develop contingency plans to mitigate any disruptions in their supply chains. This approach should include building redundancies in the system and having alternative suppliers for critical components and materials.

5.4.13 Achieve Supply Chain Resilience

Achieving supply chain resilience is critical for companies to overcome the pandemic shocks. Resilience can be achieved through various measures, such as developing more robust contingency plans, improving risk management strategies, and diversifying supplier networks (Trabucco and De Giovanni 2021). Companies can also leverage new technologies like IoT, data analytics, and blockchain to enhance supply chain visibility and traceability and anticipate and respond to disruptions. By building resilience, companies can mitigate the negative impacts of COVID and post-COVID times and position themselves for long-term success.

5.4.14 Improve Transparency and Collaboration Through Technology

Improving transparency and collaboration through technology is essential for businesses to overcome the impact of Covid-19. Companies can leverage cloud-based collaboration platforms, project management software, and video conferencing

tools. These technologies can help teams work together more effectively, streamline decision-making, and ensure everyone is on the same page. Additionally, by sharing information and data more openly, businesses can build stronger relationships with customers, suppliers, and partners, enabling them to respond more quickly to changing market conditions and maintain business continuity during and after the pandemic. Companies must enhance transparency and collaboration with suppliers, customers, and other stakeholders to identify potential risks and ensure smooth operations. This collaboration should extend across the supply chain to create a resilient and agile network.

5.4.15 Enhance Supply Chain Visibility

Enhancing supply chain visibility is critical for businesses to overcome the impact of Covid-19. Organizations can leverage technology to track and monitor their supply chain from start to end, providing visibility into potential disruptions and identifying alternative suppliers and transportation modes (Alicke et al. 2021). Businesses can make informed decisions and optimize their supply chain operations by having real-time data on inventory levels, production capacity, and delivery timelines. This enhanced visibility also enables companies to manage customer demand better and prioritize critical supplies during periods of disruption, improving resilience and mitigating the impact of the pandemic on their business. The recommendation is to use data analytics and machine learning to improve global supply chain visibility and forecasting (Shamsuddoha et al., 2023). This approach will enable companies to anticipate disruptions and optimize inventory levels accordingly.

5.4.16 Innovative Solutions in Last-Mile Delivery

Innovative solutions in last-mile delivery can help companies overcome the impacts of COVID and post-COVID times. For instance, companies can leverage autonomous vehicles, drones, and robots to streamline last-mile delivery and reduce human contact (Mohammad et al. 2023). Additionally, companies can explore alternative delivery methods such as click-and-collect, locker pickups, and delivery to secure locations. Such delivery methods can quickly reduce operational costs, improve delivery times, and enhance customer experience while mitigating the negative impacts of post-COVID times.

5.4.17 Develop Robust Contingency Plans

Developing robust contingency plans is indispensable to overcome the impact of Covid-19 on businesses. Organizations should consider various scenarios and identify potential operational risks and disruptions. They should also define response protocols, including measures to ensure the health and safety of employees, alternative supply chain arrangements, and remote working capabilities (Ash et al. 2022). Testing and refining these plans through simulations can help businesses identify potential gaps and fine-tune their responses. A robust contingency plan can navigate the uncertainty of the pandemic and mitigate its impact on their operations and bottom line.

5.4.18 Invest and Adopt New Technology

It is recommended that new technologies such as BT, AI, and IoT be adopted to enhance supply chain traceability and transparency to address the lack of traceability and transparency in supply chains (Trabucco and De Giovanni 2021). To improve supply chain visibility, identify potential disruptions, and offer real-time solutions, businesses should invest in advanced technologies such as cloud computing, big data, BT, AI, IoT and the like.

5.4.19 Ensuring Available Labor for Normal Operations

Organizations must adopt several strategies to ensure the availability of labor for normal operations during and after the pandemic (Nagurney 2021). According to Watterson (2020), companies should prioritize the health and safety of their employees by providing personal protective equipment and enforcing social distancing measures, followed by considering remote working arrangements and supporting employees struggling with mental health issues.

5.4.20 Minimize Freight and Container Handling Costs

Companies can adopt several strategies to minimize freight and container handling costs and mitigate the impact of Covid-19 on businesses. These include leveraging technology to optimize container and freight transportation routes, reducing manual cargo handling, and streamlining the supply chain process (Khan et al. 2022). Additionally, businesses can explore alternative transportation modes such as rail or sea transport to reduce costs. It is essential to balance these cost-saving measures

with other factors, such as customer demand and delivery timelines to ensure that businesses maintain optimal performance and competitiveness during and after the pandemic.

More than two hundred relevant papers from scholarly sources are listed in Google Scholar. This paper examines supply chain and pandemic-related mentionable works based on relevance and priority appearance. Table 5.1 compiled relevant supply chain bottlenecks and solutions and did not consider all of them listed in the secondary literature. It is observed that one particular solution might positively solve multiple problems fully or partially. The below section summarizes deploying a few approaches to get maximum impact on solving supply chain problems.

5.5 Principal Recommendations with Instances

This section briefly talks about principal strategies to get maximum solutions. The following are practical examples of how the above recommendations implement in various scenarios.

5.5.1 Invest in Technology

The application of technology in business operations can help address various challenges simultaneously. For instance, technology can be used to predict demand and supply, anticipate material shortages, improve supply chain visibility, and ensure transparency and traceability. Organizations can reduce costs, improve operational efficiency, and increase customer satisfaction by leveraging technological solutions. Technology can also help businesses identify and mitigate risks and respond to changes in the market faster.

5.5.2 Diversify Supplier Base Using Multiple Sources

Manufacturers can minimize the risk of supply chain disruptions by identifying alternative suppliers for critical components. By doing so, they can ensure that their production processes continue uninterrupted even if their primary suppliers encounter challenges. For example, semiconductors and electronic sensors should not rely on a single country or company to avoid a sudden shortage. This proactive risk management approach can help manufacturers minimize downtime, reduce costs, and maintain customer satisfaction.

5.5.3 Enhance Supply Chain Agility

The pandemic has highlighted the need for businesses to enhance their supply chain agility by building more flexible and resilient supply chains to respond more effectively to unexpected disruptions, such as pandemics, natural disasters, or geopolitical events. This requires investments in digital technologies, diversification of suppliers, and collaboration across the supply chain. For example, a fashion retailer can adopt flexible manufacturing processes such as on-demand or made-to-order production, which help reduce inventory carrying costs, improve responsiveness to changing customer demands, and avoid overproduction.

5.5.4 Emphasize Efficient HR Policy Related to Employee Health and Safety

Businesses must prioritize employees' health and safety to continue operating during emergencies. To ensure the safety and well-being of employees during crises, HR should continuously monitor environmental changes and provide health and safety guidelines, along with the necessary training and tools. Businesses may secure company continuity, reduce disruptions, and uphold the confidence of their stakeholders and customers by protecting their personnel. For instance, A food processing company can implement social distancing protocols, provide PPE, and increase the frequency of cleaning and disinfecting facilities. This approach would help protect workers from the spread of disease and maintain continuity of operations.

5.5.5 Develop a Crisis Management Plan

A crisis management strategy is essential for businesses to maintain operational continuity in unexpected crises. For instance, an energy business could develop a contingency plan to address natural disasters like hurricanes or wildfires. This could involve strategies such as moving fuel from other regions, preparing backup power sources, and communicating with customers and stakeholders in affected areas. Regularly updating and testing the plan can help companies respond effectively to crises and minimize disruptions.

5.5.6 Focus on Sustainability and Continuous Improvement

To handle pandemics and other crises, businesses can focus on sustainability and continuous improvement practices. Prioritizing sustainability can improve supply

chain resilience and stakeholder trust. At the same time, continuous improvement practices, such as regular reviews and testing of crisis management plans, can help companies adapt and learn from experiences to better prepare for future crises. For instance, an e-commerce company can monitor customer feedback and optimize logistics operations to reduce delivery times. Also, a food company may adopt sustainable packaging materials such as biodegradable plastics or paper-based packaging.

The above recommendations and instances help the decision and policymakers make the necessary changes in supply chain processes to respond to any disaster quickly.

5.6 Concluding Remarks

When everything is performing well, considering potential disasters is often absent from professionals' minds. The COVID-19 pandemic has shown severe flaws and weaknesses in the functioning of the existing supply chain operations. The sudden disruptions to global transportation and other unforeseen events have highlighted the importance of supply chains that are resilient, adaptive, and agile. Due to the ongoing effect of the pandemic on supply chains, there is a growing sense of urgency to address the issue as delays, shortages, and significant financial losses can occur for businesses. Following the abovementioned prescriptive suggestions, businesses can create more resilient supply chains that can withstand future crises. To achieve this, companies should invest in risk management methods, enhance transparency and collaboration, adopt new technologies, and focus on sustainability. These steps can help create a more adaptable and robust supply chain better prepared for future challenges. Every business operation has a unique process and needs customized solutions to handle existing and potential supply chain bottlenecks.

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Part III
Building Sustainable Supply Chains with Advanced Technologies

Chapter 6
Impact of Digitalisation in Developing Procurement and Supply Chain Resilience in the Post Pandemic Era—A Study of the Global Manufacturing Sector

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Abstract This study aims to investigate the impact of digitalisation in developing procurement and supply chain resilience in the post pandemic era within the context of global manufacturing sector. A systematic literature review identifies 63 conceptual and empirical studies while focusing on five global manufacturing sectors including: automotive, electronics, food & beverages, apparel, and pharmaceutical sectors. The primary elements that affected the impact of pandemics on procurement and supply chain resilience are: policy management, globalisation, and geographical characteristics. Pandemics create substantial risks and hazards in terms of demand variations (surges and dips) and price increases, depending on the sector. Other risks and hazards differ across industries, such as supply shortages, financial difficulties for suppliers, declining working capital, and worker health issues. Good practises for mitigating the impact of pandemics on procurement and supply chain resilience primarily include: boosting agility, adopting staff safety measures, and expanding E-commerce. Manufacturing firms can adopt a range of digital technologies to diversify

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their supply chains and to pro-actively engage in more collaborative relationships with stakeholders throughout their supply chains in order to develop more resilient supply chains in the post pandemic era. This study provides a practical set of recommendations regarding how to successfully develop supply chain resilience in the post pandemic era by employing a range of digital technologies including: Artificial Intelligence, Block Chain Technology, Augmented and Virtual Reality; Additive Manufacturing; Internet of Things, Big Data Analytics etc. in addressing risk and resilience challenges across a range of global manufacturing sectors.

Keywords Systematic literature review (SLR) · Digitalisation · Resilience · Risk · Manufacturing · Artificial intelligence · Block chain technology · Augmented and virtual reality · Additive manufacturing · Internet of things · Big data analytics · Automotive · Electronics · Food and beverages · Apparel · Pharmaceutical

6.1 Introduction

The recent pandemic outbreak exposed many of the procurement and supply chain risks (PSCR) that have long existed in all manufacturing sectors. For example, supply chain delays due to the pandemic affected 94% of Fortune 1000 companies (Sherman 2020). 75% of firms have seen negative or very negative effects, and 55% expect to lower their growth projections or have already done so (Accenture 2020a). Apple had to delay deliveries of its new products to the market, due to the closure of Foxconn plants in China (Feiner 2020). Nissan plants in Asia, Africa, and the Middle East also stopped manufacturing cars (Contractor 2020). Pharmaceutical companies struggled to keep natural market flow because they depend on the importation of raw materials from their suppliers located across the globe.

6.2 SLR Methodology

This work followed the Systematic Literature Review (SLR) methodology (Tranfield et al. 2003; Denyer and Tranfield 2009). This work followed the 5 main phases of SLR: (1) Planning; (2) Searching; (3) Screening; (4) Extraction and Synthesis; and (5) Reporting (Pilbeam et al. 2012).

6.2.1 Planning

In the planning stage, the following 4 review questions were designed that form the basis for 4 main research themes for this work:

1. What are the key factors that influence the impact of Global Pandemics on PSCR?
2. What are the major risks and challenges caused by Global Pandemics on the PSCR?
3. What good practices can be adopted in managing the impact of Global Pandemics on the PSCR?
4. What actions can be taken to develop and control a more resilient procurement and supply chain in the post pandemic era?

6.2.2 Searching

The searching phase of the work was based on the key search terms defined as under in Table 6.1.

Using Boolean operators such as "AND" and "OR" the search strings were created to cover the main aspects of the research as shown in Table 6.2.

6.2.3 Screening

Inclusion and Exclusion Criteria

To improve academic rigour and journal article quality, search results were limited to peer-reviewed, scholarly publications with references (see Table 6.3). Since the pandemic the world is now facing is COVID-19, the publication dates were restricted to 2020 onwards. The sources were likewise limited to English. The rationale for this was that the time necessary to acquire and correctly translate articles exceeded the possibilities for reducing linguistic prejudice. Where search strings yielded a high number of articles, the subject area was restricted to 'business' for relevance reasons. This was accomplished through the use of business-specific databases such as ABI/Inform (ProQuest) and EBSCOhost: Business Source Complete, as well as by

Table 6.1 Definitions of key terms

Key term	Definition
Resilience	"The ability of a supply chain to both resist disruptions and recover operational capability after disruptions occur" (Melnyk et al. 2015)
Procurement	"Procurement is the process of finding and agreeing to terms, and acquiring goods, services, or works from an external source, often via a tendering or competitive bidding process" (Laffont and Tirole 1993)
Supply chain management	"Supply chain management is the management of the flow of goods and services and includes all processes that transform raw materials into final products" (Fernando 2021)
Pandemic	"An epidemic occurring over a very wide area, crossing international boundaries, and usually affecting a large number of people" (Last 2014)

Table 6.2 Keywords and search terms used in the systematic review

Number	1		2		3		4
Keyword	Resilience		Supply Chain/Procurement		Pandemic		Sector
Alternative Words	Resilien* OR Risk* OR Flexib* OR Strength* OR Resistan* OR Framework	AND	"Supply Chain" OR "Demand Chain" OR "Value Chain" OR "Supply Network" OR Procure* OR Sourc* OR Buy* OR Purchas*	AND	"Pandemic" OR Covid*	AND	Automo* OR Vehicle* OR "car"

Table 6.3 Inclusion and exclusion criteria

No.	Characteristic	Inclusion criteria	Exclusion criteria
1	Article language	English	Any other language
2	Publication date	2020 onwards	Pre-2020
3	Article type	Academic journals, industry reports, government documents, magazine articles	Books, working papers
4	Subject area	Business, management, and accounting	Natural sciences, computer sciences, medical science, engineering
5	Industry fields	Logistics, procurement, supply chain	Other industries
6	Unit of reference	Automotive, electronics, food and beverages, apparel, pharmaceutical retail	Other sectors

limiting Scopus results to the subject of 'Business, Management, and Accounting'. During the screening procedure, 335 papers were rejected. The reasons for exclusion varied. The primary cause for rejection was that articles specifically did not focus on manufacturing sector industries. Also, many articles did not concern procurement, supply chain or any of the five industry sectors which were rejected on relevance grounds. Articles from around the world were looked into as the geographic area for this study was global and not region specific. A total of 63 articles were finally included for the extraction and synthesis stage of SLR.

6.2.4 Extraction and Synthesis

Data was extracted into templates separating and recording quantitative and qualitative data into categories allowed for statistical analysis of descriptive data and also served as a link between the content and research objectives. The information captured comprised (1) author of the article; (2) title of the article; (3) document name; (4) journal title; (5) date of publication; (6) volume; (7) number; (8) page numbers; (9) paper type; (10) geographical location; (11) context/industry; (12) sample size; (13) data collection method; (14) method of data analysis; (15) study characteristics; (16) key findings related to research questions; (17) abstract; (18) key words; and (19) organisational field. The flow diagram for the SLR process is shown in Fig. 6.1.

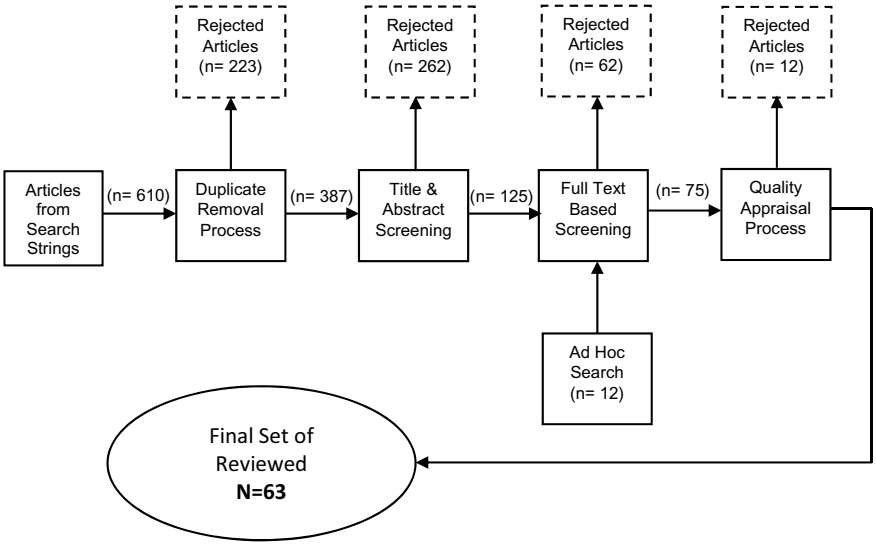

Fig. 6.1 Summary of the SLR process (Tranfield et al. 2003)

6.2.5 Reporting

In the reporting stage of SLR, descriptive and thematic findings of the research are presented as follows.

6.3 Descriptive Findings

6.3.1 Chronological Distribution

Since the sources were restricted to years 2020 onwards, the chronological distribution of sources is almost similar in 2020 and 2021 (see Fig. 6.2). The reason for this could be that as COVID-19 is an ongoing pandemic at the time of writing this paper, newer articles are getting published with different strategies on risk mitigation. Having up-to-date sources also offers a more accurate picture of the potential hazards and resilience building initiatives in the manufacturing sector.

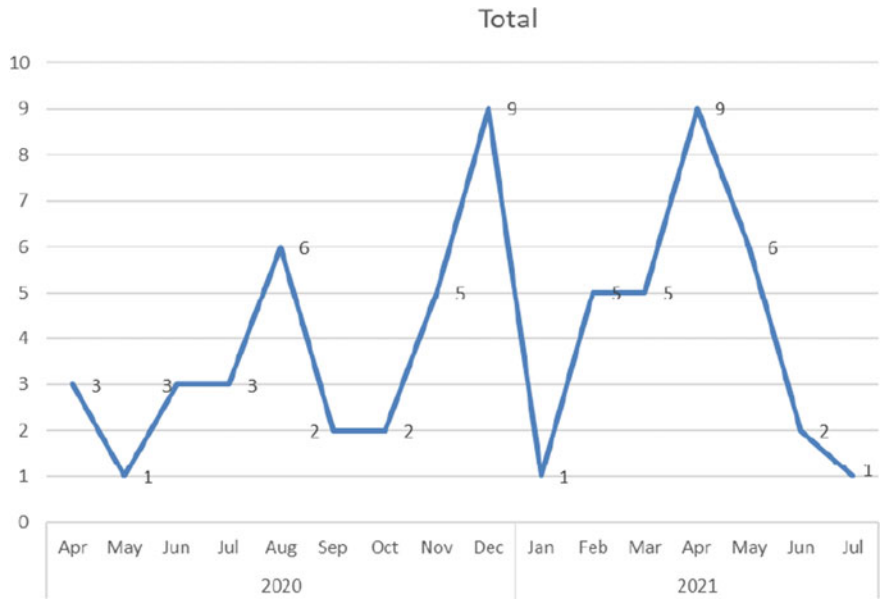

Fig. 6.2 Chronological distribution of documents

6.3.2 Geographical Distribution

The geographic distribution of documents indicates a high proportion of these focussed on global region (36), followed by North America (9), Asia (4) and Europe (4). The global viewpoint originated from reports written by multinational businesses with colleagues stationed in different places, or from papers that included examples from industries located in different geographic areas. Furthermore, the inclusion criteria of only considering publications written in English may have reduced the quantity of papers in geographic domains of investigation (Fig. 6.3).

6.3.3 Sector Distribution

Figure 6.4 shows how the sources were grouped based on the manufacturing industry they belong to. The visualisation indicates a clear majority of sources offering a perspective of research that included the food (43%) manufacturing industries. This could be because food is more important in everyday life than other manufacturing industries. Another large proportion of studies were concerned with pharmaceutical manufacturing (24%) which might be due to the massive shortage or distribution problems of critical medicines due to COVID-19. 9% of the publications covered all sectors since they focused on a supply chain level across multiple sectors rather

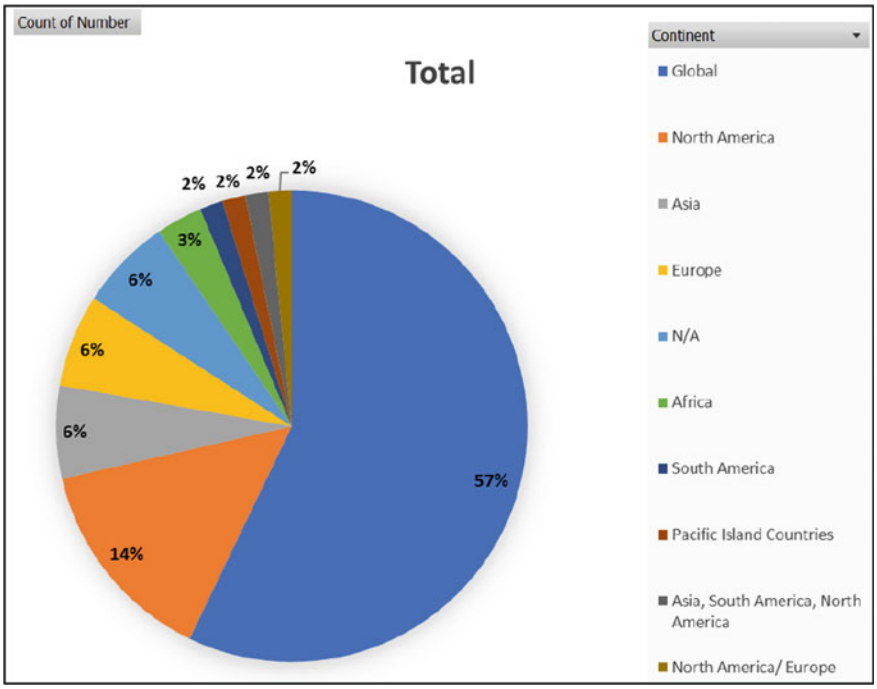

Fig. 6.3 Classification by geographic region

than a specific sector. This indicates that papers with a broad view of the business will ultimately have an impact on a broad range of industries. Lastly, the apparel (8%), automotive (8%) and electronics (8%) have relatively lesser articles thereby indicating an opportunity for further research focused on these sectors.

6.3.4 Classification by Document Type

Figure 6.5 shows that the highest share of document type were journal articles (79%). All these articles were subjected to a rigorous peer review process which increases the authenticity of this study. Also, there is a lesser risk of bias within these articles. However, due to the long publishing period, the impact or strategies of these articles may not completely be accurate or pertinent at the time of publication. Industrial reports comprised of 17% of the documents reviewed for this study due to their positive attributes such as increased relevance, industry and practitioner focused. Both journal articles and industrial literature were included to benefit from the strengths of both types of publications and try to alleviate their possible vulnerabilities.

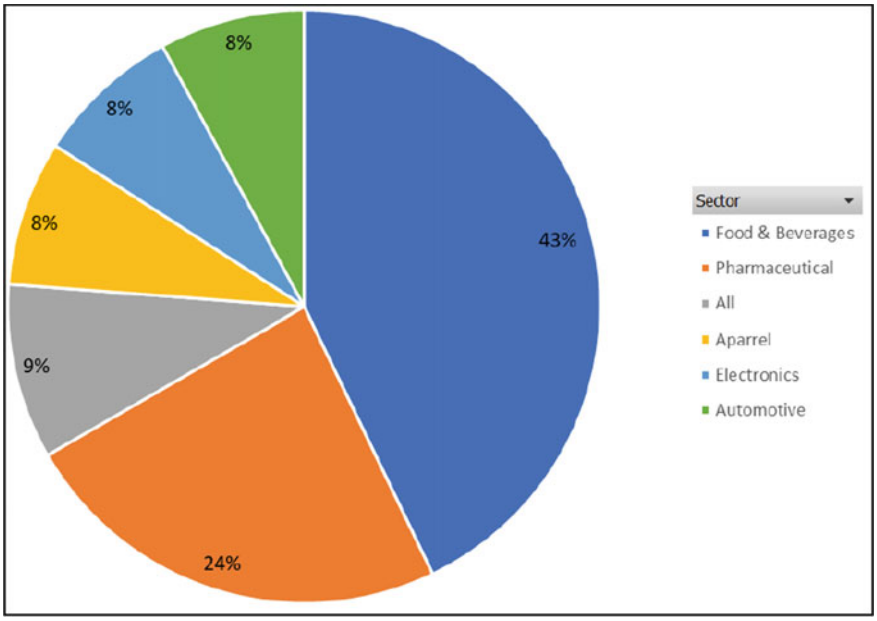

Fig. 6.4 Classification by sector

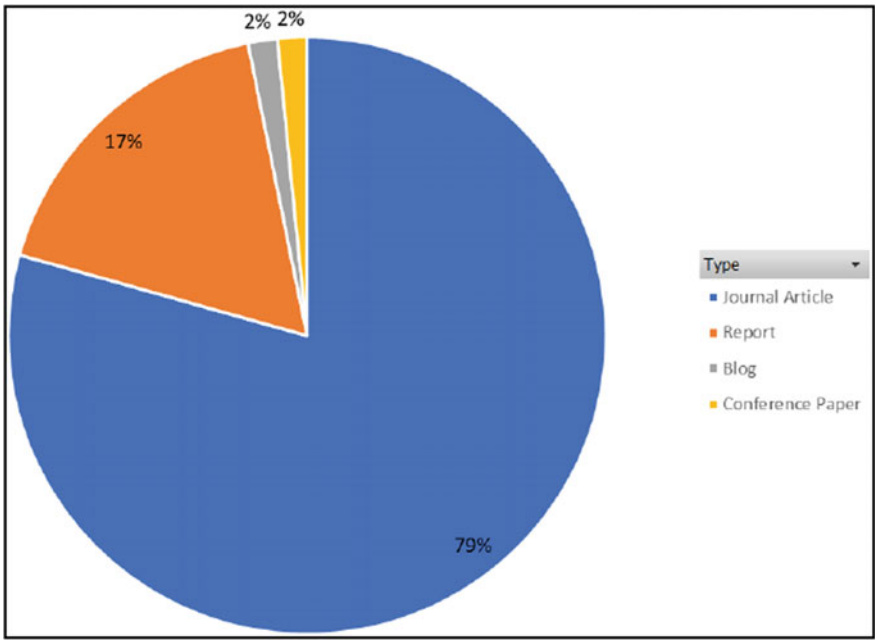

Fig. 6.5 Classification by document type

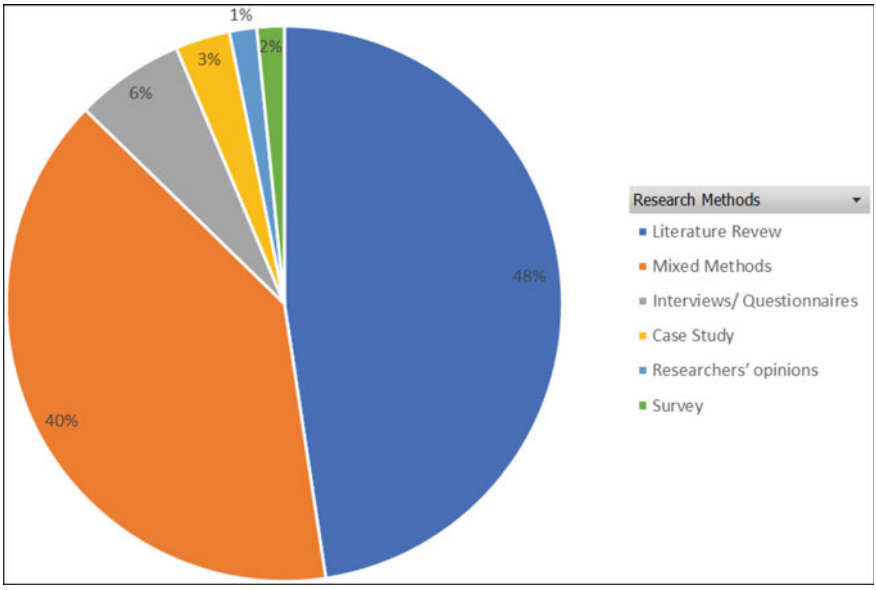

Fig. 6.6 Classification by research methods

6.3.5 Classification by Research Methods

Figure 6.6 illustrates that the study techniques utilised in the reviewed literature were diverse. Analysing at a higher level, quantitative methods were employed by 9% of the documents, qualitative by 51% and mixed methods by 40%. As a result, qualitative means get the highest weighting in both individual and combined forms. Some of this might be explained by the topic's forward looking outlook and the necessity for industry experts to assist with their organisational strategies. As a result, the seeming lack of empirical and analytical studies, particularly those based on modelling and statistical sampling, provides an opportunity for more research in this subject. Mixed methods were used to a large extent by many documents which benefits this review by analysing a richer and more comprehensive data. The variety of research methodologies used may offer a more holistic view of this subject.

6.4 Thematic Findings and Discussion

This section discusses the main research themes for this work including: (1) Influencing Factors; (2) Risks and challenges; (3) Good Practices; and (4) Actions to develop Resilient Supply Chains. These themes are discussed across the five sectors including: (1) Automotive; (2) Food and Beverage; (3) Electronics; (4) Apparel; and (5) Pharmaceutical.

6.4.1 Theme 1: Key Factors That Influence the Impact of Global Pandemics on PSCR

Automotive Sector

- **Globalisation**: Combined with considerable expansion in China and Southeast Asia over the last 10–15 years, there has been a relentless search for "lowest landed cost," which has accelerated the globalisation of the industrial supply chain. As a result, supply lead times have been longer, as have the degrees of complexity needed to keep lead time and variation risks to a minimum. The longer the true end-to-end lead time, the greater the likelihood of being exposed to variation and unexpected occurrences, increasing the problem of resilience (Handfield et al. 2020).
- **Transparency**: Only including top-tier suppliers in risk management techniques would leave organisations blind to interruptions that affect their lower-tier suppliers (Belhadi et al. 2021). It's possible for the entire supply chain to come to an abrupt halt if you don't know that a supplier hasn't started up yet or hasn't made it through (KPMG 2020).
- **Policy Management**: While just-in-time manufacturing may be the best method to produce many complicated items, the COVID-19 pandemic has revealed the drawbacks of a system that relies on all of its parts to operate precisely (Capgemini 2020). Justin-time manufacturing led in reduced raw material inventory levels across the automotive supply chain, and in the case of manufacturing, it only takes one missing component to shut down a production line, and the detrimental ripple effect of a material or parts shortage quickly spreads throughout the supply chain.
- **Geographical Factor**: The automobile industry's supply chains are made up of a large number of specialised suppliers that are grouped within regions. Early in the COVID-19 epidemic, inter-regional connections stalled the global automobile sector. The Chinese lockdown in Hubei region prompted plant closures or slowed production in North America, Europe and Asia weeks before European countries went into lockdown (Leering et al. 2020). Figure 6.7 shows the global network of countries importing vehicle parts from China.

Food and Beverages Sector

- **Globalisation**: One of the primary causes of supply shortages during the COVID-19 crisis is lean global supply networks (Fonseca and Azevedo 2020). Supply chains have expanded to low-cost regions to decrease prices as a result of globalisation, and the intricate networks of modern supply chains make them harder to control and manage during crises (Tougeron and Hance 2021). The food supply chain is complicated, including numerous elements from supplier to manufacturer to distributor to consumer, and this complexity can create gaps among the supply chain partners itself (Boyacı-Gündüz et al. 2021).

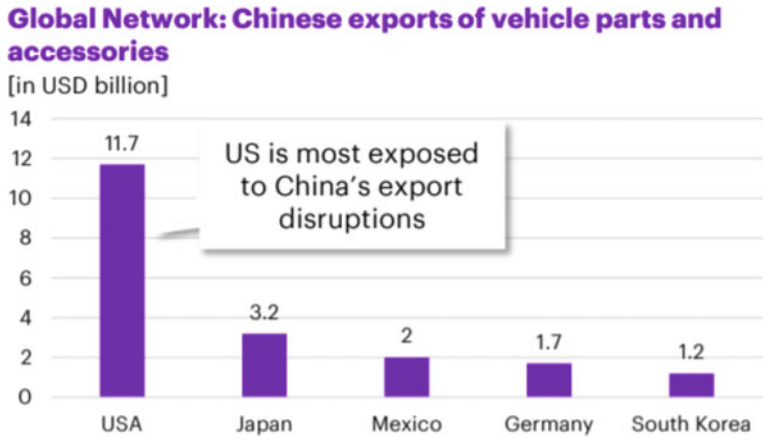

Fig. 6.7 Chinese export of automotive parts. *Source* Accenture (2020b)

- **Policy Management**: Food distribution networks that rely on just-in-time production and delivery were unable to keep up with the sudden and unexpected increase in demand across key food categories. The food retailing business in Canada, like in many other Western countries, is dominated by large, consolidated supermarket chains with significant purchasing power and an emphasis on cost reductions. The just-intime approach to food retailing has significantly increased efficiency due to low inventory levels and rapid product transfers. In typical circumstances, these are efficient and responsive supply networks. Retail buyers prepare for anticipated increases in client demand (such as during major holidays or festivals) by signing contracts with key suppliers that call for increased supply at the appropriate time. Due to a lack of inventory and capacity buffers, the system seems to be less sensitive to disturbances outside of the usual (Hobbs 2020; Kumar 2020; Marusak et al. 2021; Weersink et al. 2021).

Electronics Sector

- **Globalisation**: Semiconductor firms operate in a complex ecosystem, collaborating with various raw material, assembly, test, packaging, and equipment suppliers and partners throughout the world. This has resulted in crucial component/material shortages during COVID-19 (Accenture 2020c).
- **Geographic Factor**: A significant number of the minerals and parts utilized in electronic gadgets are mined and fabricated in China, which was the first nation to adopt a lockdown to forestall the spread of the COVID-19 pandemic, causing worldwide interruptions in manufacturing (Althaf and Babbitt 2021; Fig. 6.8).
- **Critical Minerals**: Numerous elements utilized in present day electronic gadgets have been added to the extending rundown of vital minerals, showing their importance to trend setting innovation and the likelihood that their inventory would be disturbed because of international commotion, catastrophic events, or even worldwide medical conditions. Cobalt, for instance, is a significant part of lithium-ion

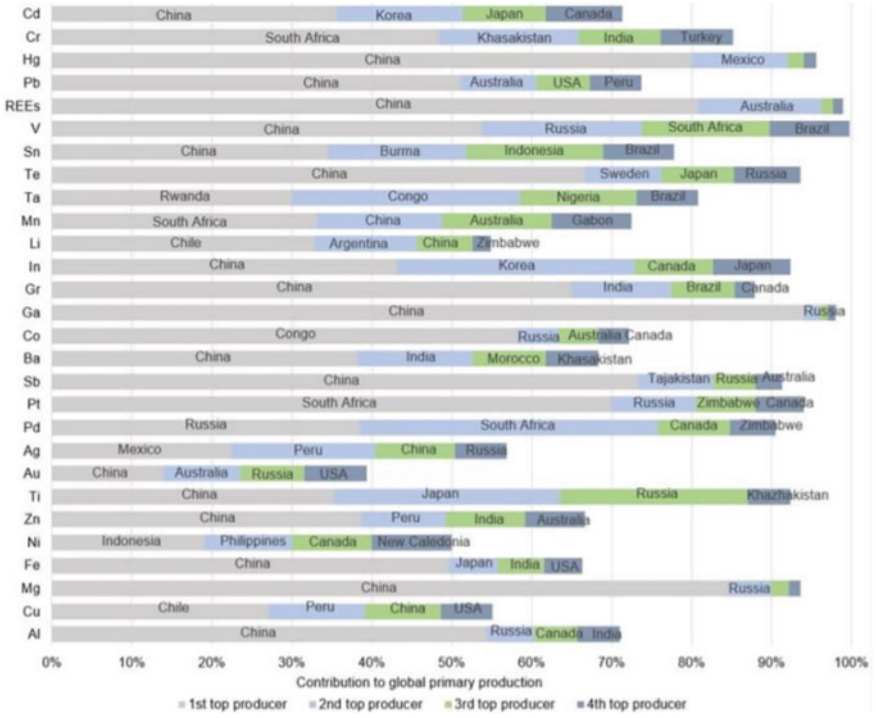

Fig. 6.8 Geographical distributions of mine production of electronics materials. *Source* Althaf and Babbitt (2021)

batteries utilized for energy storage in gadgets and electric vehicles, and it has quite recently been assigned as an essential mineral by the Democratic Republic of the Congo, the world's top cobalt maker. Additionally, rare earth elements like neodymium, dysprosium, and europium, which are significant parts of super durable magnets and electronic showcases, have been added to the US DOE basic mineral rundown. These elements highlight the thought that the requirements on material stock chains experienced during the COVID-19 pandemic were just a hinting of the approaching bottlenecks and weaknesses that this sector would face later on (Althaf and Babbitt 2021).

Apparel Sector

- **Globalisation**: Since the introduction of global SCs, the fashion sector is experiencing a growth in the number of sourcing sites as well as consumer markets, resulting in increasingly complicated supply chains. Complex networks are more likely to be subject to significant disruptions, where a problem in one component of the SC might influence following components in the value chain (Maersk 2020; McMaster et al. 2020).

- **Geographic Factor**: Globally, China continues to be the world's largest garment producer by a wide margin, accounting for 36% of worldwide apparel exports - more than double that of its nearest competitor, Bangladesh (Maersk 2020). The COVID-19 pandemic first caused delays in the production of fashion products in China, which eventually resulted in the closure of stores globally (Taqi et al. 2020). Figure 6.9 shows the major exporters and importers of apparel and clothing accessories globally.

Pharmaceutical Sector

- **Globalisation**: Specialized divisions of labour exist in global supply networks. Different sites produce specialised components and end products, increasing the chain's efficiency. Disruptions or poor items at one site, on the other hand, might imperil the whole chain (Gereffi 2020; Kumar and Pundir 2020). Globalization and outsourcing have been proposed to amplify the intensity of a disruption while

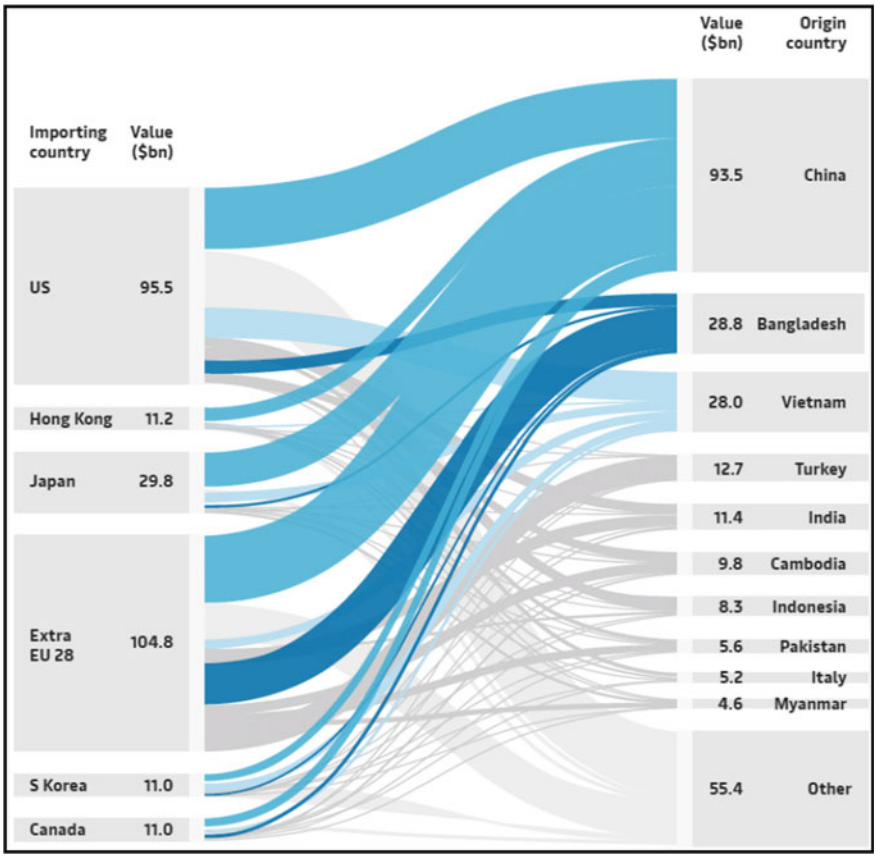

Fig. 6.9 Global imports of apparel and clothing accessories, 2019. *Source* Maersk (2020)

also increasing hazards. These efforts result in longer and more complex supply chains, which limit visibility while increasing susceptibility, plant performance, manufacturing costs, and supplier innovation (Yaroson et al. 2021).

- **Policy Management**: The subsequent lines are based on (Bhaskar et al. 2020; Gereffi 2020; Sodhi et al. 2021). Supply chains for critical medical equipment altered dramatically after World War II as a result of many goals, such as increased quality and lower costs for the general public. The high costs of implementing technical breakthroughs, along with the restricted resources of tax-paying patients, have resulted in an increase of the trade-offs between these aims throughout time. Lean supply chain was utilised to enhance financial and operational performance. However, frugality has resulted in adversity. Because of labour and supply-chain cost savings, medical supplies, which serve as "buffers" in times of crisis like COVID-19, have been decreased. In the midst of emergency, for example, COVID-19, "lean" ways to deal with the medical care production network model have incited deficiencies of PPEs, are unsuitable for medical services and may risk financial, worldwide wellbeing, and public safety. The Department of Health and Human Services reported that "US had 12 million N95 masks and 30 million surgical masks as of March 4, 2020, accounting for just 1% of the actual needed quantities during the pandemic". Similarly, the National Medical Stockpile of Australia was estimated to have just "12 million masks in stock in January 2020".
- **Geographic Factor**: Responses from every province in Canada pointed out that vital items were heavily reliant on one geographic source (for example China). According to several authorities, "90% of health goods in North America are obtained from manufacturers in China as a result of low prices". The reliance on a single geographic supplier was frequently associated with a lack of significant local manufacturing or supply capability (Snowdon et al. 2021).
- **Poor Visibility**: Healthcare organizations cannot manage their PPE procurement risk unless they have transparency throughout the supplier chain. Without knowing their suppliers' real identities, companies are unable to inspect them for adulteration and other quality concerns, further delaying the response to a pandemic (Omar et al. 2021; Scala and Lindsay 2021; Sodhi et al. 2021).

6.4.2 Theme 2: Major Risks and Challenges Caused by Global Pandemics on the PSCR

Automotive Sector

- **Limited Supply of Vehicle Parts**: When COVID-19 first emerged in China in December 2019, there was an immediate impact on the local automobile sector, with manufacturing temporarily closing. Since more than 80% of the global automotive supply chain is located in China, these closures have created production bottlenecks for global original equipment manufacturers (OEMs) (KPMG 2020). Even when manufacturing reopened in China, there were safety precautions in

place in workplaces, such as social distance, which significantly limited output capacity. Later when COVID-19 spread across the globe, legal and trade restrictions, such as closed borders, increased the shortage of required parts for the OEMs and limited distribution of supplies (Accenture 2020b; KPMG 2020).

- **Declining Working Capital/Liquidity**: Automobile manufacturers have been forced to slash employees because of the continuing pandemic's impact on their sales. According to Aston Martin Lagonda Global Holdings Plc, the company's employment would be reduced by 20%. In the UK, sales have fallen by over 89 percent compared to the same period last year (Belhadi et al. 2021). Since March 2020, manufacturers and showrooms across the EU have been forced to close due to government-imposed lockdown regulations that keep potential vehicle purchasers confined at home. Even car wholesalers like Lookers Plc were compelled by these closures to close their 12 locations and lay off 1500 people (Belhadi et al. 2021). The European Automobile Manufacturers Association (EAMA) reported in early June 2020 that factory shutdowns due to COVID-19 (30 days on average at the time of reporting) had resulted in a production loss of 2.5 million vehicles in Europe, of which approximately 617,000 were in Germany, Europe's manufacturing hub (Leering et al. 2020). The fall in demand led in a decrease in cash inflows, although short-term liabilities and wages must still be met (Accenture 2020b). Figure 6.10 shows the region-wise financial impact on automotive sector.

Food and Beverages Sector

- **Demand Shifts**: Food supply networks in Canada and worldwide have been subjected to a number of acute demand and supply shocks, which have disrupted regular supply chain operations (Hobbs 2020, 2021; Sharma et al. 2020). The most notable of them was the abrupt transition from restaurant management service to supermarkets and hypermarkets as consumers fled dining in common

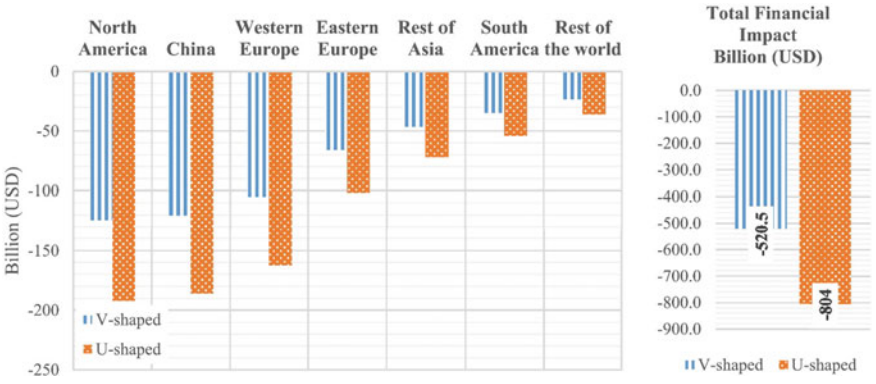

Fig. 6.10 Region-wise financial impact of COVID-19 from January 2020 to March 2021 on the automotive industry. *Source* Belhadi et al. (2021)

places outside due to virus concerns putting more stress on the food retail system (Hobbs 2020, 2021). Panic purchasing has undoubtedly contributed to a short-term increase in demand. A decrease in consumer income will have long-term effects on food supply chains, including changes to general demand and product categories. Customers are likely to grow increasingly price-sensitive, and the demand for things that are income-elastic will decline even more as people begin to avoid purchasing more expensive goods (Hobbs 2020; Singh et al. 2020a, b). Demand for flour in the UK increased dramatically as the lockdown dragged on, as people trapped to their residences began baking even more. Similarly, demand for non-perishable necessities like canned meals, rice, and pasta increased during the early days of the lockdown. In the US, demand for beef in supermarkets grew substantially, with sales growing by 92% in March 2020. The coronavirus outbreak in France sparked a surge in demand for organic and sustainably produced foods (Kumar 2020).

- **Health Concerns for Workers**: According to the Centers for Disease Control and Prevention, from late March to May 2020, 9% of US meat industry workers were infected with COVID-19, with outbreaks happening at 239 meat and poultry processing plants (Hobbs 2021). Small and medium-sized companies (SMEs) in underdeveloped countries are particularly vulnerable due to their limited financial capability to adopt hygiene and health measures (Hatab et al. 2020). When fishing, it is common for fishermen to operate in close proximity to one another inside a fishing vessel's confined space; stringent sanitary protocols and physical distance limits may also prevent workers from engaging in fishing operations (Jamwal and Phulia 2020).
- **Labour Shortage**: A lockdown has the potential to severely disrupt the operations of small and medium enterprises (SMEs) in developing countries, which rely considerably more on labour than machinery (Hatab et al. 2020). One of the factors contributing to diminished fishing activities was a labour scarcity (Jamwal and Phulia 2020). The following lines are based on (Kumar 2020; Singh et al. 2020a, b). Labour shortages in agricultural industries are being amplified by restrictions on cross border mobility and lockdowns in many countries, particularly those with times of peak seasonal labour demand or labour-intensive output. The use of seasonal migrant workers is common in many European Union agricultural estates, especially in businesses in Western Europe that are more labour-intensive. Furthermore, labour shortages caused by social distancing restrictions are beginning to influence food supply chain producers, processors, traders, and trucking/logistics firms—notably for food goods that require employees to be in close proximity. Monitoring and managing pest outbreaks such as weeds, Phyto viruses, and phytophagous insects in orchards is a critical component of apple production. However, such activities may need a level of expertise that is not always available during a crisis, and they are frequently time and labour intensive. For example, Italy has been short-staffed to combat the spread of the brown marmorated stink bug (Halyomorpha halys) in apple and pear orchards, which has likely impacted the harvest's outcome and may potentially influence the supply of apples on the market for next year (Tougeron and Hance 2021).

- **Increased Food Wastage**: Unpasteurized milk cannot be kept in the same way that other meat and poultry products can. Cases of milk dumping in US and Canada in early April were caused by a shortage of buffer capacity to retain milk that couldn't be processed quickly (Weersink et al. 2021). The overall drop in demand for dairy products from schools and restaurants has left dairy farmers with unsold raw milk, requiring millions of gallons of milk to be discarded every day, as reported in the media worldwide (Kumar 2020; Mcclements et al. 2020). Potato growers in US and the Netherlands saw a drop in restaurant demand, resulting in tonnes of unsold potatoes (Kumar 2020). The domestic food supply in China has also been affected by massive waste of agricultural goods that could not be transported out owing to the government's adoption of movement restriction measures (Memon et al. 2021).
- **Food Price Spikes**: Farmers were unable to deliver their fresh product to local and metropolitan markets during these crises. The distribution network has been hindered since travel restrictions have made it difficult for many farmers to get agricultural supplies such as fertilisers, seeds, or pesticides, and employees hesitated to go to afflicted nations for fear of becoming sick. For these reasons, the cost of basic foodstuffs has risen dramatically around the world (Aday and Aday 2020; Boyacı-Gündüz et al. 2021; Davila et al. 2021; Rivera-Ferre et al. 2021).
- **Legal and Trade Restrictions**: The major reasons for the unpredictable food supply that hampered access during the pandemic in China and India were logistical, distribution, and delivery issues. Furthermore, due to ongoing tariff and trade disputes in China, import and export were significantly hampered, resulting in a disruption in food stock availability (Memon et al. 2021). Transportation constraints and industrial closures have reduced the flow of chemicals, additives, and packaging material to seafood processing factories. The quality assurance and certification laboratories were also closed due to the lockdown and other virus containment efforts, preventing processed fish samples from being inspected for quality certificates for export (Jamwal and Phulia 2020).

Electronics Sector

- **Semiconductor Price Hikes**: There is a direct influence on the material supply chain when mining, processing, and manufacturing processes are unexpectedly halted or modified due to an event like a pandemic. Price spikes can arise as a result of a mismatch between supply and demand caused by such disruptions (Althaf and Babbitt 2021). Figure 6.11 shows the estimated change in semiconductor sales by demand in 2020 globally.
- **Shortage of Materials**: After pandemic mitigation efforts like lockdowns forced mining and metal processing facilities to shut down, demand for electronics grew while supply of essential materials decreased (Accenture 2020c; Althaf and Babbitt 2021; Aylor et al. 2020). Furthermore, due to global travel limitations, labour-intensive OSAT (Outsourced semiconductor assembly and test) operations have been affected (Accenture 2020c). It is believed that modern electronics contain more than 60 components originating in more than 50 nations and

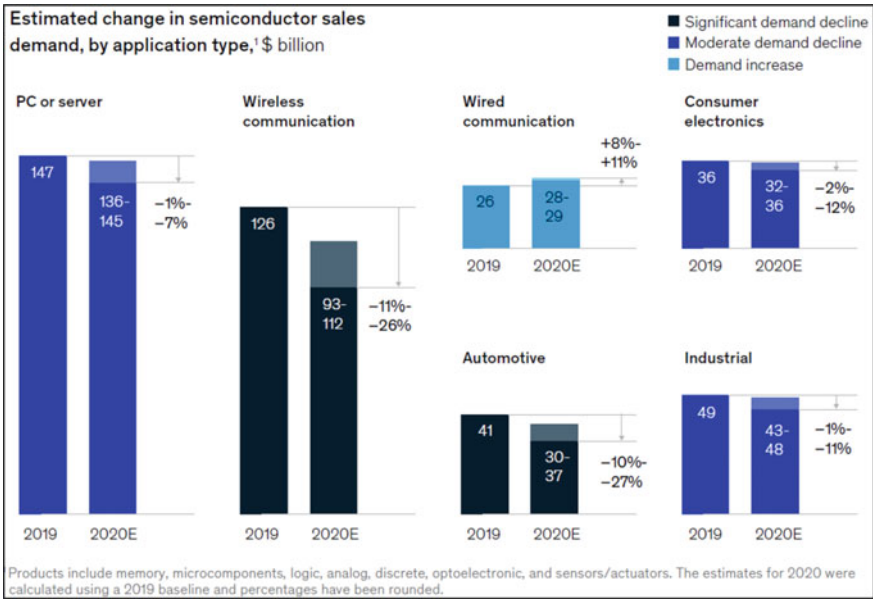

Fig. 6.11 Estimated change in semiconductor sales demand by application. *Source* Bauer et al. (2020a)

due to travel restrictions imposed by governments, transport of these materials has become challenging (Accenture 2020c; Althaf and Babbitt 2021).

Apparel Sector

- **Demand Drop**: COVID-19 has created supply and demand disruptions at the same time, with shifting consumer preferences and subsequent order cancellations having a long term impact on the global supply Chain. With stores closing and customers on lockdown, there has been a major shift in demand for fashion items. Consumer spending in Denmark fell by 27% in the seven weeks following lockdowns (McMaster et al. 2020). They asserted that the economic crisis and resulting job losses had resulted in a shift in consumer expenditure toward necessities (Chowdhury et al. 2021; McMaster et al. 2020). Inditex, the parent company of H&M and Zara, reported a 24.1% decline in sales in the first two weeks of March 2020. While Inditex stated at the end of March that the majority of its Chinese locations had reopened, 3785 more sites in 39 other countries remained shuttered. Online sales were also hit, although only slightly, with a 4.9 percent decline from 1 February to 16 March (McMaster et al. 2020). Lockouts and worsening economic conditions have reduced demand for nonessential goods, leading to order cancellations and/or the application of "force majeure" clauses by numerous firms (McMaster et al. 2020). It's no secret that COVID-19's detrimental effects have had an enormous influence on the fashion industry all around the world. By May 2020, the fashion sector had seen a 7% decrease in sales as

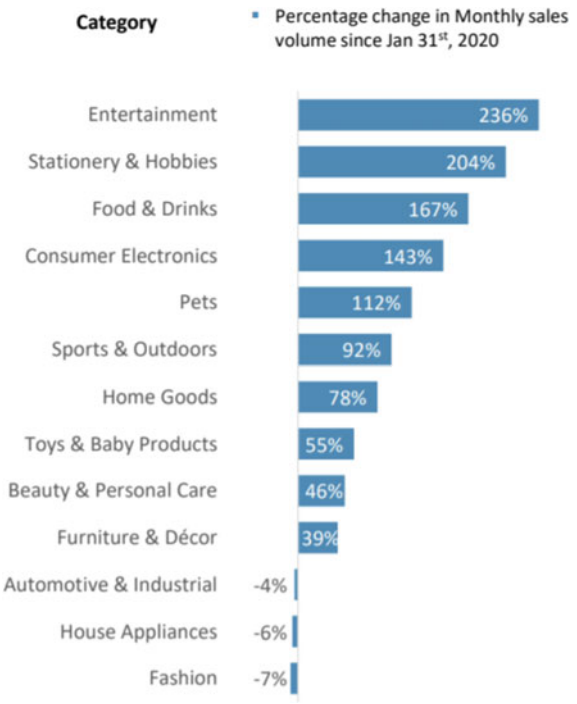

Fig. 6.12 Revenue changes by category in May 2020. *Source* Qian (2020)

a result of the pandemic's initial wave, and it was the highest affected product category as shown in Fig. 6.12 (Dewalska-Opitek and Bilińska-Reformat 2021).

- **Suppliers affected Financially**: According to the Center for Global Workers' Rights' October 2020 Research Report, "65% of suppliers were compelled to accept reduced manufactured product pricing, on average by 12%" (Dewalska-Opitek and Bilińska-Reformat 2021). The terms of payment for the clothes that were requested, manufactured, and sent also changed. Fashion retailers already offer payment terms ranging from 60 to 120 days for 66% of their suppliers. On average, suppliers get paid 77 days after the order is shipped, whereas before the pandemic, the average payment period was 43 days (Dewalska-Opitek and Bilińska-Reformat 2021; Taqi et al. 2020). The cancellation of orders during production and those completed and sent to fashion stores was another practise that put clothing suppliers in a difficult financial position, if not on the verge of bankruptcy, despite the fact that they were contractually required to be paid for these orders (Dewalska-Opitek and Bilińska-Reformat 2021; Maersk 2020; Taqi et al. 2020).

Pharmaceutical Sector

- **Low Supply from Suppliers**: Governments stepped in to protect local supplies as the corona virus spread. China, which usually produces half of the world's mask supply at a pace of around 10 million masks per day, boosted production

to 115 million masks per day during the early stages of COVID-19. The Chinese authorities, on the other hand, halted all mask exports at the same time, resulting in a gradual decline in global stocks. Germany has also barred the export of the great majority of its personal protective equipment (PPE). Vulnerabilities in the purchase of critical equipment emerged in other areas where local manufacture is not substantial. For example, Australia imports 90% of its medications and is susceptible to shortages if supply is disrupted (Bhaskar et al. 2020). Internationally functioning firms were forced to close their operations because the potential of unintentional virus spread was simply too great, resulting in major supply shortages all around the world (Chowdhury et al. 2021; Kunovjanek and Wankmüller 2020). Increased panic among consumers and businesses has skewed demand patterns and produced market anomalies, affecting the medical equipment industry's capacity to scale up production (Li et al. 2020).

- **Surge in Demand**: Early in the pandemic, the depletion of medicines, testing kits, reagents, hand sanitisers, ventilators and PPEs such as masks, gowns, gloves and face shields resulted in a rapid decrease in accessible supply at the same time that global demand rose between late February and early March (Bhaskar et al. 2020; Chowdhury et al. 2021; Handfield et al. 2020; Kunovjanek and Wankmüller 2020; Singh et al. 2020a, b; Snowdon et al. 2021; Sodhi et al. 2021). The statistics are distressing: In 2019, just 77,000 ventilators were necessary worldwide. However, as of March 11, 2020, the US alone needed 60,000–160,000 ventilators (Bhaskar et al. 2020) and required 290 million N95 masks per month to protect healthcare-workers during the pandemic (Gereffi 2020). Figure 6.13 shows the estimated production vs demand graph for N95 masks.
- **Price Hike**: Price increases were also induced by increasing demand, with the World Health Organization (WHO) revealing that surgical mask costs rose six-fold, N95 respirator prices tripled, and gown prices doubled. The combination of urgency and extended delivery times and pricing resulted in market manipulation and blatant fraud (Sodhi et al. 2021).
- **Trust Deficit Amongst Supply Chain Participants**: The COVID-19 has revealed the vulnerability of our current supply chain architecture. There has been an increase in reports of a lack of trust and pressures amongst involved entities. This is owing to the presence of middlemen or intermediaries for contracts and sourcing between supplier and buyer, who unjustly and opportunistically utilise self-serving and prejudiced business practises, underpinning a lack of transparency in reporting stock supply figures and uncertainty in transaction movements. This fosters a speculative environment, leading to a breakdown in confidence and, as a result, interinstitutional relations. In the event of a pandemic, this may have devastating effects. This is especially important because buyers don't trust data from suppliers/middlemen, especially during such crisis (Bhaskar et al. 2020; Chowdhury et al. 2021).

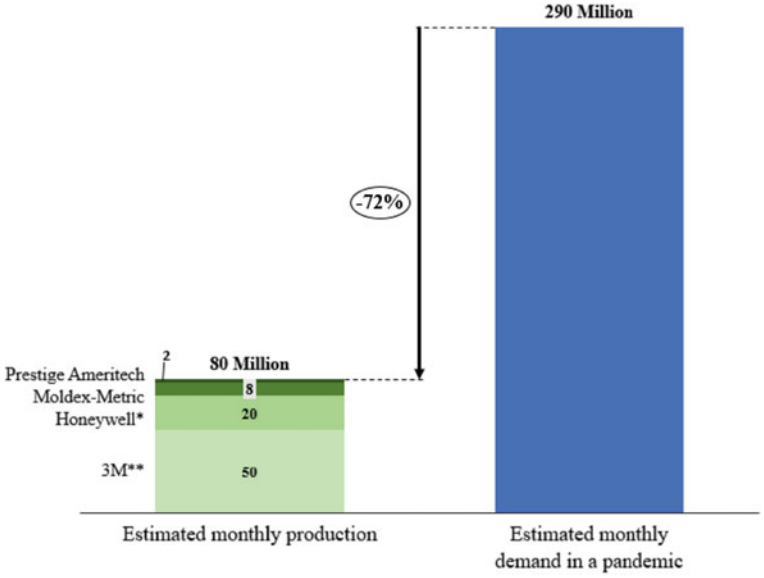

Fig. 6.13 US demand surge of N95 masks. *Source* Gereffi (2020)

6.4.3 Theme 3: Good Practices That Can Be Adopted in Managing the Impact of Global Pandemics on the PSCR

Automotive Sector

- **Increase Agility**: Agility is an important element for supply chain businesses to improve. Agility is a crucial component of supply chain resilience because it allows companies to adapt and recover quickly in the event of a disruption (Capgemini 2020). Companies must find a new equilibrium between just-in-time and "just in case." Having an adequate backup inventory of essential parts and safety stock is a significant buffer that may help to mitigate the cost effect of disrupted deliveries. It can also position businesses to handle unexpected increases in demand (Leering et al. 2020; McKinsey 2020). Organizations should not continue as normal, but rather relaunch with new, quicker procedures and technologies, as well as scalable, agile methods (Hofstätter et al. 2020).
- **Increase Visibility**: The crisis has highlighted the need of visibility throughout the supply chain. During the global crisis, companies saw a significant shift in customer demand, as well as interruptions in their supply and transportation networks. This has driven home the importance of efficient cooperation and data access for purchasing, demand, and supply planning departments in order to develop more insight into supply chains. At least 60% of companies polled want

to enhance data sharing with their network of partners, which includes suppliers, subcontractors, distributors, and retailers (Accenture 2020b; Capgemini 2020).

- **Implement Safety Measures for Employees**: Companies should perform rigorous checks on worker health, educate their employees about the pandemic, best practises for staying safe, adopt social distancing inside closed areas, and disinfect and clean the premises on a regular basis to prevent employees from becoming infected with the virus. Furthermore, if there is a case of infection among their staff, contact tracking can assist prevent the virus from spreading further. (Accenture 2020b; Hofstätter et al. 2020).
- **Products with Common Components**: Supply chain adaptability may be achieved by designing goods using common components, which reduces the usage of personalised parts in diverse product offers (McKinsey 2020).
- **Control Tower to Organise the Response**: Create an operational model for supply chain intervention reactions. Identify stakeholders, create governance, set up communication channels, and develop processes for identifying, prioritising, and managing initiatives. Appoint a single point of contact to be in charge of the response strategy. The centre, once created, organises responses ranging from defining and alignment to communication (Accenture 2020b). Figure 6.14 shows the structure of a sample control tower.

Food and Beverages Sector

- **Implement Safety Measures for Employees**: Strategies for reducing health and safety hazards to workers as early as possible included screening workers for symptoms, changes to operational procedures and practises, such as social distancing measures, protective equipment, and improved hygiene protocols, which significantly reduced (but did not eliminate) the occurrence of workplace outbreaks in meat, seafood, fresh fruits and vegetable production sectors (Aday and Aday 2020; Hobbs 2021; Hoyweghen et al. 2021; Jamwal and Phulia

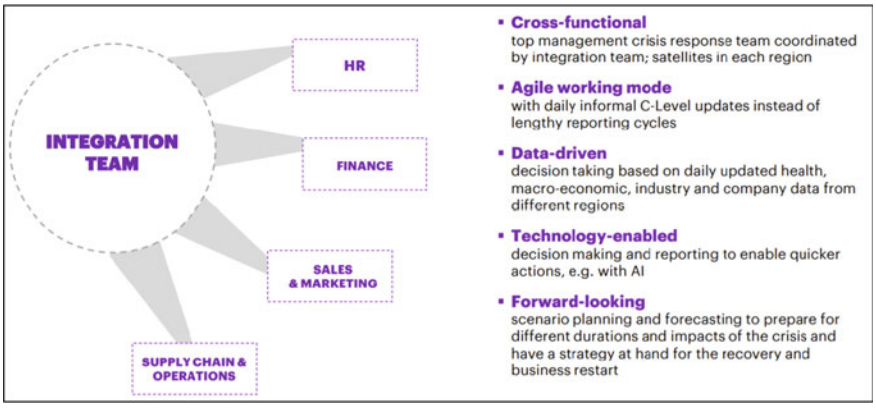

Fig. 6.14 Sample control tower structure. *Source* Accenture (2020b)

2020; Telukdarie et al. 2020). Guidelines included creating circulation plans to control people's movements, allocating employees to strict set teams to prevent a company-wide epidemic, and appointing "back-up" personnel who required to stay at home and standby to replace a colleague in the event of absenteeism (Aday and Aday 2020; Coopmans et al. 2021).

- **Government Support**: When repurposing current supply chains, supply routes built for the hotel, restaurant, and institutional trade may be inappropriate for supplying the food retailing sector because of package size and distribution infrastructure, resulting in unavoidable time delays. The Canadian Food Inspection Agency (CFIA) has made a number of temporary changes to the regulations regulating food labelling and packaging in order to make the movement of food intended for food service supply chains into the retail food sector easier. For instance, it is allowing the retail sale of Canadian-made, packaged, and labelled food products intended for food service use in Canada or the United States, and it has postponed standard container size requirements (Hobbs 2020). There are interim rules established by the Food and Drug Administration in US which allow some flexibility in aspects like product labelling to assist the food supply chain and satisfy customer demand during this crisis. Administrative and regulatory measures like these might help certain food companies deal with shrinking profit margins and splintered supply chains, addressing quality, safety, and authenticity concerns about food (Boyacı-Gündüz et al. 2021).
- **Expand E-commerce**: Food deliveries and curb side pickups have surged as on-premise food businesses have been decimated by virus transmission worries and the necessity for social distance, usually with preordering and payment on mobile devices to minimise money handling and human interaction (Mcclements et al. 2020). The growth of online grocery delivery is one aspect of food distribution that is changing dramatically as a result of the COVID-19 epidemic. There are two types of online food delivery services: specialised online-only companies like Ocado in the UK and Amazon, and traditional grocery stores that provide online delivery as an alternative. Online meal delivery may be especially useful for vulnerable people who have "remain at home" orders from governments, as well as to maintain social distancing norms in the society at large (Fonseca and Azevedo 2020; Hobbs 2020). Since virus transmission worries and the desire for social distance have decimated on-premises food services, meal delivery and curb side pickups have increased dramatically, usually with pre-ordering and payment on mobile devices to minimise physical contact. As more people get used to this type of dining experience, they may be less inclined to go to shops or restaurants, altering how food is purchased and consumed (Mcclements et al. 2020).
- **Limiting Exposure to International Market**: Losses resulting from cancellations of overseas orders might be minimised by focusing on the domestic market and fulfilling local demand. Examples include minimizing fishing activities during a crisis to only meet local demand for fresh seafood. Reduced fishing effort will help to avoid not just financial loss, but also overfishing, market overstock, and a decline in fish prices (Jamwal and Phulia 2020).

- **Increase Storage**: In response to the demand–supply mismatches that occurred across the food supply chain, a frequent solution was to lease external storage capacity to temporarily store foodstuffs, ideally on-site. As long as the products were non-perishable or could be frozen and there was enough storage space, it was feasible to store them (Coopmans et al. 2021).
- **Shorter Supply Chains**: Short Food Supply Chains are becoming increasingly important to satisfy local demand since they not only serve to cover voids, but they also provide environmental advantages such as decreasing food waste, lowering greenhouse gas emissions, and enhancing biodiversity, as well as social benefits such as linking farmers and customers, establishing a cultural identity, and improving food security and the viability of local communities. Also mentioned are benefits to the economy, such as improving farmer livelihoods and providing more local job opportunities, and health benefits, such as having access to fresh fruits and vegetables (Bassett et al. 2021; Boyacı-Gündüz et al. 2021; Coopmans et al. 2021). One way to lessen the hazards and drawbacks that come with a centralization paradigm is via decentralising food production. Storage and transportation costs can be reduced by using smaller, more localised facilities, while the environmental impact is also minimised. Reducing the distance between a company and its customers helps shorten the supply chain, which reduces emissions and energy use while in transportation and storage. Decentralization enhances the supply chain‘s flexibility and gives customers access to more fresh and natural products (Aday and Aday 2020; Marusak et al. 2021).

Electronics Sector

- **Expand E-commerce**: As the physical channel is effectively closed down, shift all marketing and sales focus to the internet. Reduce spending to a more concentrated product and brand portfolio. Extend features as much as feasible to create a full purchasing experience, particularly to increase chat and customer communication (Ahola 2020).
- **Increase Agility**: Increase the frequency of the "sales and operations planning" to analyse and deal with sudden variations in demand (Accenture 2020c; Ahola 2020). Co-create and crowdsource products with customers and competitors to address the immediate demands of the worldwide COVID-19 response, particularly in the medical device and communications industries (Ahola 2020).
- **Reducing Capital Expenditure**: Large capital cuts are necessary if businesses require more money to survive a crisis. However, for firms in a stronger financial situation, massive cutbacks may not be the greatest option. Many of today's best firms decreased capex less than their competitors during the Great Recession, putting them in a better position to prepare for growth once the economy began to recover. With the current crisis, businesses that move on with plans to develop next-generation products, acquire equipment, or make other comparable expenditures will be ready if demand spikes when the economy improves. Those that delay may find it difficult to catch up, as some advances might take years (Bauer et al. 2020b).

Apparel Sector

- **Shorter Supply Chains**: Firms should choose for simpler supply chains since complicated networks are more prone to significant disruptions, where a snag in one component of the supply chain might affect subsequent components in the value chain (McMaster et al. 2020).
- **Information Sharing about Risks**: In the event of an interruption, producers and retailers may modify inventory decisions to minimise overstocking or understocking, reducing the bullwhip effect and its associated costs by sharing real-time Supply Chain risk information (McMaster et al. 2020).
- **Expand E-commerce**: Because online product offers are easier to update than physical ones, businesses with online storefronts may quickly modify their product offerings to meet changing demand circumstances. ASOS, an online-only store, reported "cancelling less than 1% of their Spring/Summer 2020 inventory". When brick and mortar stores fail, companies with a strong digital presence should be able to sustain sales (McMaster et al. 2020).
- **Increase Agility**: Firms might consider creating buffers to reduce the ripple impact when a single supplier is compromised. This may be accomplished in two ways: by establishing an inventory buffer or "safety stock" of critical components and products, or by establishing a time buffer by delaying the manufacture of goods when demand is uncertain (McMaster et al. 2020; Taqi et al. 2020). In the first months of 2020, the Kering Group relocated its inventory from China to locations with less severe economic effect. Instead of sending all items to locations at the beginning of each fashion season, the company's strategy involves replenishing product supply as they are sold. The company has been able to respond to variations in demand with exceptional agility because no products became "stranded" in China during the initial breakout. By June 2020, China's economy is expected to be back on track, and the business will be in a position to replenish its Chinese equity holdings. Since fashion businesses should react to actual demand, rather than projecting demand and refilling at the beginning of the season, they should think about restocking as needed. Because of this method, we're better able to adapt to demand disruptions (McMaster et al. 2020). Padini, a Malaysian clothing company that operates in Malaysia, Brunei, Cambodia, Thailand, Myanmar, and other Middle Eastern countries, is strengthening its online platforms through omni-channels throughout the transformation phase. Padini fosters the growth of online businesses by creating innovative online shopping experiences and improving the convenience of online purchasing for customers (LEU 2021). Timberland engages customers and communicates with purchasers through an e-commerce platform, social media, and mobile apps (LEU 2021).
- **3D Printing**: The problem with traditional manufacturing is that you can only pick two of the triangle's points. That is, you can have any two aspects: speed, quality, or cost. The promise of next-generation additive manufacturing machines is the simultaneous fulfilment of all three (LEU 2021). This would also lower the number of individuals employed in manufacturing plants, therefore minimizing the impact of social distance, lockdowns, and other industry-wide disruptions.

Pharmaceutical Sector

- **Increase Agility**: Another method for more flexibility is to use medicines with similar strengths or an acceptable therapeutic alternative at the appropriate dose, or to use existing combinations of products as feasible choices for patients' treatment continuity (Yaroson et al. 2021). A pandemic requires the integration of shops and warehouses at many levels, such as central, state and district warehouses to maintain responsiveness and meet demand (Chowdhury et al. 2021).
- **Increase Visibility**: Visibility through information sharing across the supply chain was found as an effective method for resuming operations following an interruption. The flow of stock and demand levels were the focus of information sharing. Primary care responders, for example, stated that they were able to carefully monitor product flow from their suppliers using an online database, and that when the stock level was on red, it indicated that there was an issue with items, necessitating more inventory planning (Handfield et al. 2020; Scala and Lindsay 2021; Yaroson et al. 2021). By mapping supply networks, visibility may be improved, allowing future interruptions and their repercussions to be predicted. This mapping can help develop node/supplier-specific strategy (Chowdhury et al. 2021). Centralized supply chain management highlighted the transparency of product inventories to regions and organisations, where product identification and location were clear, and product utilisation rate (e.g., burn rate) was well defined in each area or organisation. Centralized supply chain management allowed for a highly coordinated procurement approach in which product distribution throughout a region or province was prioritised to each health institution based on need (Snowdon et al. 2021).
- **Joint Decision Making**: Jointly developing strategies with supply chain partners assisted all Supply Chain players in limiting the negative impact on patients' treatment continuity and operations. In terms of operations, one of the manufacturers demonstrated the value of collaborative planning by partnering with all stakeholders to establish plans for dealing with the approaching disruption. Meetings were held to inform Supply Chain participants about the disruption and its duration. They agreed on the best course of action together, and it was implemented to avoid operational and financial losses, as well as the death of patients (Chowdhury et al. 2021; Yaroson et al. 2021).
- **Additive Manufacturing**: Additive Manufacturing (AM) is a method that allows items to be manufactured directly from computer-aided design files by adding one layer after another, providing for unrivalled design freedom, resource efficiency, manufacturing flexibility, customisation and responsiveness. The capacity of additive manufacturing to create replacement components on-site in distant regions that are inaccessible by traditional means of delivery improves the availability of precious resources. AM also allows you to respond effectively to changing and difficult-to-predict product demand (Kunovjanek and Wankmüller 2020; Manero et al. 2020; Singh et al. 2020a, b). Prusa3D, a 3D printer company, created and verified the Prusa PRO Face Shield design. By June 2020, it produced and supplied almost 200,000 shields aimed at medical professionals in the Czech Republic

(Manero et al. 2020). Stratasys, a 3D printer company, gathered together business and educational partners with the capability of swiftly producing face shields for distribution to a nationwide coalition of needy hospitals and medical locations. With over 100 active manufacturing locations, the alliance supplied over 100,000 3D printed shields to more than 200 medical facilities across US (Manero et al. 2020).

6.4.4 Insights and Implications for Post-Covid Practice: Theme 4: Actions That Can Be Taken to Develop and Control PSCR in the Post Pandemic Era

Automotive Sector

- **Digitalisation of Supply Chain**: The COVID-19 pandemic and its influence on global supply chains have forced companies to recognise the operational benefits of utilising digital approaches to make better decisions and manage disruption (Belhadi et al. 2021).
- **Big Data Analytics (BDA)**: Certain firms have found BDA to be a huge assistance in increasing their information handling and optimising their supplier selection process before and during the interruption, which has improved their predictive capacities against possible interruptions (Belhadi et al. 2021; Ibn-Mohammed et al. 2021). Big data, intelligent systems, and linked ecosystems will help predict a disruptive event. Identify each component's possible risk exposure all the way up the supply chain, with end-to-end transparency, and prioritise risks accordingly (Accenture 2020b).
- **Automation**: Process automation (physical and transactional) is required in industries since most of the fixed expenses of a manufacturing organisation, such as planning, production management, and requirements management, can be automated to a degree that was not previously achievable as a result of which it can work with minimal human intervention (Belhadi et al. 2021; Chowdhury et al. 2021; Ibn-Mohammed et al. 2021).
- **Internet of Things (IoT)**: Remote equipment status monitoring and maintenance scheduling are now possible thanks to industrial IoT techniques and smart devices. Advanced self repair algorithms can diagnose product quality based on component pictures, identify the cause of problems based on planned activities, and enhance part quality through equipment and system reconfigurations using AI and deep learning algorithms. The capacity to self-repair reduces the need for human intervention in frequent inspection and testing, therefore lowering health hazards and labour costs. Furthermore, domain experts' travel requirements are significantly decreased, allowing them to comply with pandemic travel prohibitions and limit their exposure to hazardous situations (Li et al. 2020).

- **Artificial Intelligence (AI)**: Set up and use AI in asset management to offer current cash flow and predictions in real time (Accenture 2020b).
- **Supply Chain Diversification**: China is one of the world's major suppliers of vehicle parts, which means that any interruption in the nation will damage the whole automotive supply chain. To avoid this predicament, auditing and geographically diversifying supply chains is critical to limiting risks from any one nation or area whenever feasible but simultaneously keeping production in China to keep operational expenses low (Aylor et al. 2020; Capgemini 2020; Leering et al. 2020; McKinsey 2020). In addition, companies should prequalify or acquire a number of suppliers for critical components to reduce their reliance on a single source in the case of a supplier's financial, quality, pricing, or capacity change or a factory shutdown for whatever reason. This reduces sourcing time, and prequalified suppliers can swiftly take over work when the main supplier's operations are disrupted (Aylor et al. 2020). Sub-tier suppliers, on the other hand, who rely heavily on a single client for a significant portion of their revenue, are subject to financial difficulties if that customer closes or ceases doing business with them (McKinsey 2020). Suppliers should constantly seek out new prospect clients, both locally and globally, to ensure that they have numerous customers and can continue company operations in the case of an interruption.
- **Collaborative Buyer–Supplier Relationship**: Supply chains should collaborate and share goals and information in order to build strong coordinated strategies that promote quicker recovery (Belhadi et al. 2021). Since Tier 2 suppliers and beyond have a direct impact on Tier 1 supplier order fulfilment performance, it is critical that Tier 1 suppliers strengthen their connections and interactions with them. So they have considerably more time to work with Tier 1 suppliers on alternative plans or to adjust supply chain plans proactively to keep facilities functioning at maximum efficiency within any Supply side restrictions. As a result of facility shutdowns, suppliers at all levels should expect substantial reductions in essential suppliers' scheduled delivery performance. This will provide suppliers early warning of shortages and allow top tier suppliers to respond effectively if they increase their attention on inventory, production scheduling, and the condition of supplier shipments. Another advantage of having stronger collaboration between the buyer and supplier could be "those at the top of a value chain have a vested interest in preserving the supplier networks on which they depend. In the aftermath of the crisis, some companies accelerated payments or guaranteed bank loans to give key vendors a lifeline" (McKinsey 2020).

Food and Beverages Sector

Digitalisation of Supply Chain

- **Automation**: The relative cost of labour as an input is likely to have risen as a result of the requirement for social distance and, as a result, slower processing line speeds, as well as other steps to promote worker health and safety. "Increased use of robotics on manufacturing and processing lines decreases reliance on labour,

particularly in loading/unloading, packaging and quality control which involves uniform and repetitive tasks“ (Aday and Aday 2020; Hobbs 2021; Mcclements et al. 2020). Automation in handling systems should be accelerate in order to decrease touchpoints and prevent the transmission of the virus. Palletization of goods, conveyor systems, robots, autonomous trucks and drones for intralogistics etc. are examples of these technologies (Kumar 2020; Mcclements et al. 2020; Mogili et al. 2020). Automated feeders, water quality monitors, and farm monitoring equipment can assist aquaculture farms minimise their need on manual labour. (Jamwal and Phulia 2020). “Innovative indoor farms are emerging that will shorten the supply chain and make them more robust to future disruptions. They employ high degrees of automation and sensors to monitor crop growth and quality, reducing the risk of cross contamination and viral transmission” (Mcclements et al. 2020).

- **Blockchain**: Food and beverage businesses throughout the world should examine technology developments such as blockchain to increase visibility and transparency in their supply chains. Food data (e.g.: location tracking, expiry date, place manufacture) and agricultural activities may be tracked using blockchain technologies. This would help to build confidence among the many elements in the agri-food chain (Hobbs 2020, 2021; Jamwal and Phulia 2020; Memon et al. 2021).
- **Artificial Intelligence (AI)**: “AI can be used to manage farm activities in order to decrease skilled labour expenses and optimise feed, water, and energy consumption in order to prevent stress and disease in fish” (Jamwal and Phulia 2020). In order to fulfil the changing needs of a supply chain, “AI can be utilised to forecast shortages, demand surges, direct supplies and provide companies with the essential steps to be implemented” (Kumar 2020; Sharma et al. 2020).
- **Internet of Things (IoT)**: Wearable technology enabled by IoT allow for real-time monitoring of employees’ health. Workers may even track their personal health and submit verifiable data with the employer. In conjunction with strong facial recognition and other biometric identification systems, monitoring body temperature can detect symptoms of sickness such as a high fever. These can help workers in manufacturing plants, meat productions sites where they are always in close proximity to one another. Figure 6.15 represents a conceptual digital food supply chain integrating IoT, AI, Blockchain and automation.
- **Supply Chain Diversification**: Because agri-food exporters rely heavily on a few destination markets, they are sensitive to market fluctuations and shocks. As a result, agri-food SMEs should focus on export diversification, increase regional cooperation, create the conditions for facilitating agri-food SMEs’ access to new export markets, and develop an institutional and regulatory framework that supports agri-food SMEs’ ability to compete in global markets (Hatab et al. 2020; Mogili et al. 2020). Also, the supplier base should be diversified to enable companies along the food chain to quickly react when certain input sources are exposed due to transportation or logistical problems (Kumar 2020; Sharma et al. 2020) and if possible, spread evenly across the globe and locally to avoid geographical concentrations. Having local suppliers helps shorten the supply chain and makes

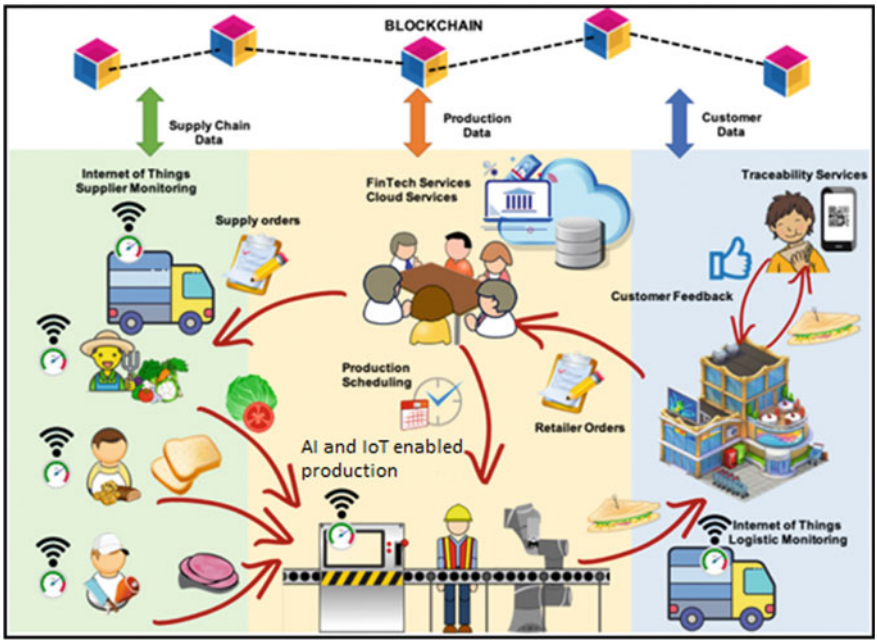

Fig. 6.15 Conceptual digital food supply chain model (Duong et al. 2020)

it more flexible while global suppliers could prove to be more cost effective. A smaller danger is perceived by companies who sell fresh fruit both locally and internationally during the COVID-19 pandemic. Exporting SMEs in the agri-food industry that own farms and are more vertically integrated have stronger control over the supply chain, and these traits allow them to reinforce their distribution network, reduce production costs, collect upstream or downstream profits, and minimise the implications of supply chain risks. Furthermore, agri-food SMEs that sell in several markets have higher market elasticity and are able to make product and market modifications in the face of unexpected market shocks (Hatab et al. 2020; Jamwal and Phulia 2020). "Food supply chains sourcing from local suppliers of in-season fresh produce will be less vulnerable to cross-border disruptions in imports or systemic failure at a major choke point within a larger supply chain (e.g., the shut-down of a major processing plant due to labour shortages)" (Carlson et al. 2021; Davila et al. 2021; Hobbs 2020).

- **Collaborative Buyer–Supplier Relationship**: In a moment of crisis, the establishment of deeper ties and commitment within buyer–supplier partnerships are rewarded through reciprocal risk sharing and increased efforts to maintain robust supply networks. Strong partnerships aid in the resilience of the supply chain. In times of hardship, suppliers are more willing to go the additional mile (e.g., priority restocking) for a customer that has built a collaborative, supportive relationship with its suppliers. Collaboration between buyers and sellers fosters confidence

among supply chain participants as well as flexibility in responding to unforeseen swings in demand or unplanned supply interruptions (Hobbs 2020, 2021; Sharma et al. 2020). Companies may enhance transparency and visibility by keeping close relations with tier 1 and tier 2 suppliers, as well as knowing how strong they are during times of disruption, what the impact of the disruption will be, and how to make better informed decisions for them to bounce back (Mogili et al. 2020; Sharma et al. 2020).

Electronics Sector

Digitalisation of Supply Chain

- **Omni-channel retail**: It's possible that some of the sales won't return to the physical channel at all Companies must focus on developing flexible, omni-channel capabilities. Include a direct-to-consumer route that may function independently, as a complement to, or even as an alternative for, current physical channels (Ahola 2020).
- **Artificial Intelligence (AI)**: Forecast models relying on past data will be rendered obsolete for an extended period of time. Create sophisticated demand forecasting capabilities based on forward-looking data in order to spot granular changes before they become problems. Consider AI to help you get deeper insights and respond more quickly to changes in the environment (Ahola 2020). Companies may enhance their operations and financial outcomes even further by implementing AI and real-time advanced analytics (Accenture 2020c). Machine learning and other AI skills can detect trends and abnormalities that highlight risks and exceptions.
- **Cloud Computing**: Companies should move applications to the cloud, if possible, to increase workers' remote access capabilities, allowing them to work from anywhere with internet connection during mobility limitations such as lockdowns (Accenture 2020c; Ahola 2020).
- **Automation**: Companies should upgrade their position within the value chain, by investing in robots and automation of tasks such as packing, handling delicate components, assembling electronic boards etc. (Leering et al. 2020). This would help organisations by boosting output by minimising manufacturing errors, material waste, recalls, and labour reliance while applying social distancing measures (Leering et al. 2020).
- **Supply Chain Diversification**: Expanding sources is especially important considering the small number of nations that now produce electronics materials. The production of more than half of the materials considered is concentrated in only three nations, accounting for almost 75% of world output. Additionally, for nearly all materials, more than half of production is concentrated in one or two nations, with China usually serving as the primary producer (Althaf and Babbitt 2021). Industries should plan their production capacity and architecture such that they are not reliant on a single source or nation (Accenture 2020c; Ahola 2020; Bauer et al. 2020a). Sourcing resources from alternative sources, whether through "closed-loop electronics recycling" or "open-loop commodities markets", may provide

a way to minimise economic and environmental repercussions while also diversifying supply chains to reduce geopolitical and societal risks associated with disruptions such as COVID-19 (Althaf and Babbitt 2021).

- **Collaborative Buyer–Supplier Relationship**: Developing good relationships between buyer and supplier helps in building trust between all parties involved in the supply chain. This can improve transparency throughout the supply chain which means information regarding any disruption experienced by any single entity will be conveyed quickly throughout the supply chain and would help other members of the chain take effective decisions to mitigate the risk or at least reduce the impact. Sharing common goals can benefit both parties by entering new segments in the market, cost reductions or raise profits. Stronger relationships can also help in more flexible payment terms, financial assistance and combined research and development. During times like the COVID-19 pandemic, many suppliers struggling with their capital management can receive financial assistance if their clients are stable commercially. Along with attempts to build relationships, a focus on contract fortification is also beneficial in order to prevent future supply chain partners from engaging in opportunistic behaviour (Chowdhury et al. 2021).

Apparel Sector

Digitalisation of Supply Chain

- **Automation**: In addition to reducing human error in manual inventory counting, robots and drone technology optimises space usage, increases accuracy, and improves operational efficiency (LEU 2021). When inventory levels fall below a threshold, these systems can create notifications and reorder items, freeing up time and resources for humans to concentrate on exception-based needs of high value.
- **Big Data Analytics**: Integrate all supply chain information from downstream stakeholders to upstream stakeholders to minimise any disruption (LEU 2021), which makes the supply chain transparent, and disruptions experienced by any member can be quickly identified. It is possible to utilise advanced analytics and expertise to understand how demand changes in real time, and how they influence inventory and operating capital (LEU 2021). It's then feasible to create the much-needed versatility and flexibility from manufacturing to market and purchase raw materials using this information. Nike utilised predictive analytics to strategically mark down items and cut production early on to minimise effect and as a result, Nike's sales dropped less than those of some of its competitors (McKinsey 2020).
- **Artificial Intelligence**: Lockdown measures have accelerated the shift from in-store to online purchasing, and it is now more important than ever to provide online experiences that give the same levels of creativity, discovery, and customer service as instore. AI helps businesses to expand customised online experiences, refocusing campaigns, and interactions at a minimal cost in order to fulfil customers' desire for that in-person touch. Instead of depending on significant discounting, AI promotes greater revenue uplift throughout the outbreak at full pricing.

- **Supply Chain Diversification**: By diversifying the supply network, the supply chain can be more responsive (Leering et al. 2020; Taqi et al. 2020). COVID-19 shut down numerous ports across the world and prevented raw material supply from many trusted sources for manufacturing companies. Consequently, a backup supplier pool was formed to ensure company continuity. Numerous large manufacturing companies had no alternate sourcing routes during this pandemic, causing them to lose millions of dollars in unfulfilled orders (Taqi et al. 2020). In addition, firms should consider expanding into new markets. As a result, the effect of cancelled orders owing to COVID-19 limitations in a particular region would be reduced (Maersk 2020; Taqi et al. 2020). Firms should also look into establishing alternative modes of transport to their business regions (Maersk 2020). This would clearly need both time and financial commitments, but it would result in a far more powerful platform to address issues that might otherwise jeopardise the entire organisation.
- **Collaborative Buyer–Supplier Relationship**: A collaborative buyer–supplier relation benefits both parties by allowing them to grow their businesses and have a beneficial economic effect. During the pandemic, suppliers faced problems such as order changes after placement, order cancellations, longer payment terms, price negotiations but collaborative relationship solves such problems. During the pandemic, Inditex, for example, paid for products received in their warehouses within 90 days. They did not modify order parameters (volume, specifications, deadline, etc.) after placing an order, and they did not seek suppliers for any discounts or price reductions. Contracts signed with suppliers did not include any financial consequences for contract noncompliance, such as late delivery, incorrect specification, and so on (Dewalska-Opitek and Bilińska-Reformat 2021). For example, they worked with other organisations to develop measures to mitigate the economic impact of COVID-19, preserve garment workers' income and health while also helping businesses weather the COVID-19 crisis. This was especially important for companies in countries with underdeveloped health and social protection systems (Dewalska-Opitek and Bilińska-Reformat 2021). Fashion firms may benefit from building strong strategic alliances with major logistics providers that are capable of actively managing and optimising supply chains on a continuous basis, partners who can be an important component of their entire supply chain resilience playbook (Maersk 2020).

Pharmaceutical Sector

Digitalisation of Supply Chain

- **Blockchain**: Use blockchain technology as a connector for direct links between supply chain stakeholders (buyers and suppliers), which may potentially address gaps, decrease inefficiencies, automate audit, allows instantaneous ordering, payment, and reporting on process-related activities, and therefore develop more robust systems (Bhaskar et al. 2020; Omar et al. 2021). During large-scale crises, supplies must be tracked in real time using immediate, traceable, and verifiable techniques to prevent self-serving behaviours such as PPE hoarding. Blockchain

represents a significant step forward in minimising such behaviours and allowing more effective supply chain responses (Handfield et al. 2020; Kumar and Pundir 2020).

- **Internet of Things (IoT)**: Blockchain technology paired with IoT will enhance the pharmaceutical supply chain's efficiency, scalability, reliability, transparency, and visibility (Joseph Jerome et al. 2021; Kumar and Pundir 2020). Table 6.4 shows the list of benefits for a pharmaceutical supply chain of integration of blockchain technology and IoT (Fig. 6.16).
- **Augmented Reality (AR)**: AR is useful because it makes it easier to integrate existing resources and employees, and it displays an exact replica of the actual job and method. With AR, you can easily train a semi-skilled staff how to utilise it. As an example, customers may easily visualise the item they're purchasing in a 3D setting rather than a 2D landscape thanks to augmented reality. It's possible to approach all buyer–supplier contacts in a fresh way with procurement meetings that bring people and organisations together and increase cooperation, including bidding, negotiating, and signing contracts (Joseph Jerome et al. 2021).
- **Artificial Intelligence (AI)**: AI is a technology that uses trial and error and self-learning algorithms to execute and accomplish activities that are heavily reliant on human intelligence. The pharmaceutical business has benefited greatly since it

Table 6.4 Benefits of blockchain-IoT integration

Activity in PSC	Blockchain	IoT	Benefits
Manufacturing of product	Registration of product with unique id and generation of a new block with product id on the blockchain network	Product id is scanned and transferred to the cloud	Transparency, trust, product details and data security
Transported to distributor/warehouse	Generation of smart contract block, verification of manufacturer's contract, generation of transaction id, product id and block id verification	Path tracking and product id verification, GPS and smart devices (camera, sensors, temperature control etc.) enabled truck	Visibility, traceability, reliability, quality tracking, transparency, trust, immutability
Received at distribution centre/ warehouse	Verification of contract of the supplier, transaction id, product id and block id	Track the location of the product and update the specified quantity (information is stored in cloud)	
Distribution centre/ warehouse to retailers/ hospitals	Enabled the verification of product id and order id	Helps in continuous tracking of products till it reaches to the final customers	

Source Kumar and Pundir (2020)

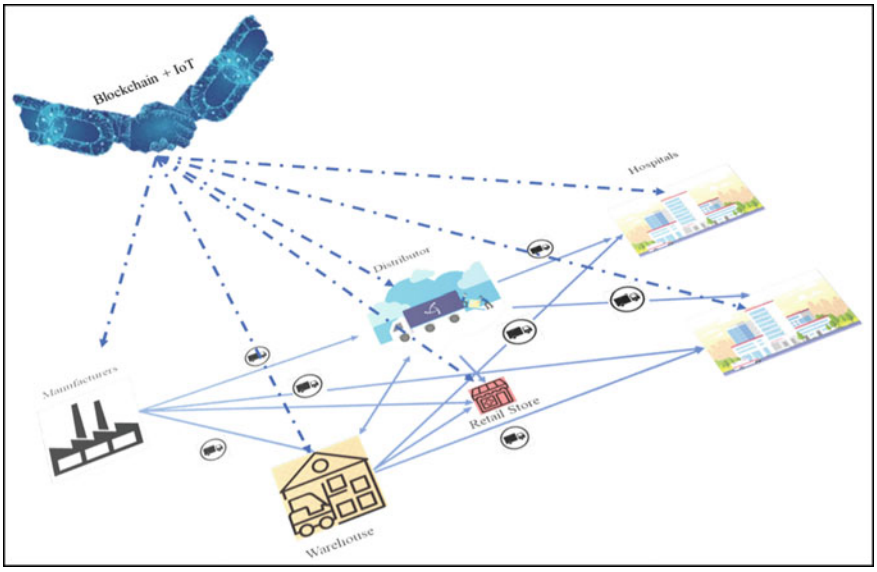

Fig. 6.16 Blockchain-IoT integrated supply chain model. *Source* Kumar and Pundir (2020)

aids in early detection, clinical development, simplicity of diagnosis, and a variety of other situations. AI has also aided in the management of COVID-19's effect through surveillance and prediction, therapies, vaccinations, diagnostics, and societal control (Joseph Jerome et al. 2021). It will also be easier to find and recall medicines with the assistance of location traceability, maps, and visualisations (Joseph Jerome et al. 2021).

- **Big Data Analytics (BDA)**: BDA is recognised to improve a firm's performance through improving planning, investment, control, and coordination. BDA may also be used to produce environmentally friendly goods and developing BDA capabilities is the recommended approach for businesses aiming to develop sustainable supply chain results (Joseph Jerome et al. 2021). The combination of BDA and AI technologies can increase industrial flexibility by allowing machines to make autonomous choices based on data analysis (Joseph Jerome et al. 2021), reducing human participation and therefore ensuring that output does not suffer during Covid limitations.
- **Supply Chain Diversification**: Pharmaceutical companies should increase their capabilities in their own nation to handle security issues for vital items (Gereffi 2020). This can also assist vulnerable people obtain access to quality medications, lessen reliance on overseas contributions, and make it easier to monitor the entry of counterfeit medicinal goods into emerging markets. Moreover, local businesses frequently create items for the local people, quality controllers have better control and the local economy benefits from the money given by local employees.

By diversifying its supply sourcing across several suppliers situated in different geographical locations, a company may substantially minimise its supply risks. This lowers supply risks associated with obtaining numerous raw materials and packaging materials from a single source, as well as peculiar geopolitical risks (Fonseca and Azevedo 2020; Scala and Lindsay 2021; Sodhi et al. 2021). Establish sourcing strategies with both a low-cost factory with higher supply time or and a faster costlier supplier. The flexible factory or supplier would accommodate short-term variations for various goods, avoiding lost sales. In the event that the cost-effective plant is disrupted, the flexible unit can act as an interim solution until the cost-effective plant resumes operations (Sodhi et al. 2021).

- **Collaborative Buyer–Supplier Relationship**: The Pharmaceutical Supply Chain may better plan and prepare for disruptions by sharing resources with supply chain partners. This resource sharing is only possible if strategic partnerships are created that allow parties to exchange timely information, infrastructure, and technology. A community pharmacist who participated in strategic partnership practises said that their suppliers often gave up-to-date information about impending interruptions as well as infrastructure to stockpile (Yaroson et al. 2021). It's possible to leverage the manufacturing technologies of different communities by working together. There is expertise and desire in organising assistance activities across existing communities in the United States, including municipal, educational, and defence oriented networks. Many libraries, makerspaces, and other public organisations now have access to additive manufacturing equipment. When communities are under duress, these manufacturing centres may be well suited to solve local concerns. They may also help medical facilities with prototype and project-based issue resolution thanks to their technical design skills (Manero et al. 2020).

6.5 Conclusion

Focusing on five global manufacturing sectors, this study investigated the impact of digitalisation in developing procurement and supply chain resilience in the post pandemic era. Policy management, globalisation, and geographical characteristics were identifies as the primary elements influencing the impact of pandemics on procurement and supply chain resilience. Various pandemic related risks were identified including supply shortages and financial difficulties for suppliers. Boosting agility, adopting staff safety measures, expanding e-commerce and employing a range of digital technologies were recommended as possible ways to mitigate these risks in the post pandemic era.

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Chapter 7
Obstacles in Disruption and Adoption of Green Supply Chain Management (GSCM) Practices by Manufacturing Industries

Sherbaz Khan, Syed Imran Zaman, and Shujat Mubarik

Abstract Unforeseen events like natural disasters, political turmoil, or pandemics can throw supply chain management off track. It may cause the supply chain to slow down or even halt, which may cause shortages or unmet orders. Increases in demand or shortages in supply can also result. Long-term consequences of disruptions to the supply chain include higher costs, lower efficiency, and lower customer satisfaction. Supply chain managers should have backup plans ready to implement in the event of an unexpected disruption to continue operating as smoothly as possible despite the setback. Green supply chain management (GSCM) is a strategy to lessen businesses' adverse environmental effects. This study seeks to determine what reasons prevent the industrial sector of Karachi from adopting GSCM methods. The existing literature research and the opinions of industry managers were used to identify the study's difficulties. This study has clarified the objective and problem statement of this research article. This study will also offer managers and stakeholders insights into the importance of green supply chain management for removing such obstacles and ensuring successful sustainability in performance.

Keywords Implementation · GSCM · Disruption · Environment · Barriers · Manufacturing · Obstacles · GSCM · Manufacturing Industries · Adoption of GSCP

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7.1 Introduction

To preserve an environmentally friendly atmosphere and sustainability and at the top for achieving a competitive advantage, implementing a Green Supply Chain Management (GSCM) strategy is necessary at this point (Mubarik et al. 2021). In the modern industrial environment, green supply chain operations are gaining popularity, and manufacturing companies are incorporating green activities into their supply chains to safeguard the environment (Khan et al. 2023a).

We have narrowed down the factors preventing Karachi's industrial companies from adopting GSCM methods. Environmentally friendly supply chain techniques benefit businesses and manufacturers greatly (Miao et al. 2022). Manufacturing businesses must overcome several obstacles to implement these GSCM principles (Mubarik et al. 2021). These difficulties lead to failure, which poses real challenges for GSCM implementations. Recognizing these obstacles is a crucial and important first step (Rahman et al. 2020). The book chapter makes several contributions, including identifying implementation challenges for GSCM based on a thorough literature analysis and manufacturing managers' perspectives from Karachi's manufacturing sector.

7.1.1 Background of the Study

The two most important problems for all businesses today are environmental preservation and sustainable development (Khan et al. 2021a). The integration of supply chain management into organizational processes was first observed in the 1990s and was viewed as a strategic advantage for businesses worldwide (Mubarik et al. 2022). Organizations in such a dynamic and complex environment must manage and operate supply chains where markets are highly volatile (Khan et al. 2021a).

Organizations must identify their requirements and create projects and strategies to develop an ecological administration framework compatible with their organizational structure and sustainable, ensuring the long-term availability of society's economic, environmental, and social resources (Miao et al. 2022). The industrial industry in Karachi does not frequently embrace green supply chain activities. This paper aims to pinpoint the main barriers to implementing green supply chain management in Karachi's manufacturing businesses (Khan et al.).

Green supply chain management is an effort to lessen the adverse environmental effects of industries worldwide. However, in a nation like Pakistan, particularly in the city of Karachi, which is regarded as the center of industries, GSCM practices are still in their infancy and have not been widely adopted by most organizations.

From the above issues, the objectives of this chapter are as below;

1. To identify the main chapter, obstacles to GSCM implementation in Karachi's industrial sector.
2. To assess the manufacturing sector of Karachi's knowledge of GSCM processes.

From the above objectives, we derive the following book chapter questions;

1. Which green supply chain management (GSCM) techniques are essential for the long-term success of organizations?
2. Which green supply chain management firms most frequently employ (GSCM) techniques?
3. Do green supply chain management (GSCM) techniques affect an organization's capacity for sustainable growth?
4. Do GSCM practices offer strategic assistance for the application of concepts?
5. Do HRM departments contribute to or engage in practices supporting the green supply chain?

7.2 Literature Review

7.2.1 Green Supply Chain Management (GSCM)

Environmental protection activities are being considered worldwide due to rising carbon emissions and climate change in recent years (Mubarik et al. 2021). Green supply chain management is one of the biggest initiatives launched by the industrial sector to reduce the detrimental environmental effects of value chain operations (Wang et al. 2015). Additionally, green supply chain management (GSCM) is a comprehensive system for managing supply networks to safeguard the environment and reduce consequences that degrade the planet (Khan et al. 2022d). Green innovation entails improving products and processes to lessen or restrict adverse environmental effects (Lin et al. 2020).

Businesses typically need to go on a nonlinear path of book chapters to successfully carry out supply chain greening initiatives (Miao et al. 2022). This journey may involve modifying or revising their products, creating new procedures, and creating new action plans (Silva et al. 2019). Environmentally friendly materials, processes, and output are used in GSCM when there is a known end date for the product, and it has a recyclable or disposable structure (Papalexi et al. 2016). It happened due to environmental change, a lack of shared resources, increased global temperatures, and campaigns by certain NGOs to improve the environment and society (Nguyen et al. 2022).

7.2.2 Conceptual Background of Green Supply Chain Management (GSCM)

Green supply chain management (GSCM), which prioritizes environmental security, effectively reduces the unfavorable side effects of dangerous items (Khan et al. 2021). Additionally, implementing GSCM may assist businesses in reducing the production

of hazardous waste, cutting expenses, increasing efficiency, and utilizing much less operating energy (Mubarik et al. 2021).

Even though green supply chain management has several advantages, Pakistani businesses haven't yet adopted it (Tumpa et al. 2019). GSCM is the term used to describe possibly integrating intuitive reasoning into supply chain management (Miao et al. 2022). GSCM relates to focusing on an organization's natural performance and that of its clients, suppliers, and partners. The four Rs—Reuse, Reduce, Rework, Refurbish, Reclaim, Recycle, and Remanufacture—are used by GSCM (Agyabeng-Mensah et al. 2020).

7.2.3 Factors Impeding the Adoption of Green Supply Chain Management (GSCM) in Karachi

In underdeveloped nations like Pakistan, green supply chain management has yet to take hold. The issue is whether it is crucial to create a sustainable environment for business in an era of globalization (Khan et al. 2021). To adhere to stringent environmental regulations, retailers in developing nations like Pakistan (Karachi) must embrace more environmentally friendly techniques. The next obstacles were gathered from the viewpoints of many parties, such as the government, corporate structures, demand and supply flows, and others.

7.2.3.1 Government Policies

Environment-friendly activities must be successful for government choices and policies to be effective. It is often challenging for policymakers to interfere in the non-sustainable production system and implement sustainable production methods (Stahl et al. 2019). Instead of enacting rules and regulations, governments might encourage the implementation of green supply chain projects by expanding incentive programs. Governments should also collaborate with industry experts to reach a compromise on GSCM. The Pakistani government is engaged in green building initiatives and tree planting, but more must be done to fully persuade multinational corporations to implement GSCM standards across their organizations (Tumpa et al. 2019).

7.2.3.2 Attributes of Green and Eco-friendly Materials

The most significant challenge with GSCM systems is the higher expense of producing green products (Nguyen et al. 2022). When firms implement green technologies early on, there is an additional cost associated with procuring and using green raw materials. Therefore, implementing GSCM projects in Karachi city is discouraged by the worry of financial regression.

In addition to the financial risk, there is also the danger that operational expenses may rise due to the incompatibility of raw materials with other materials, the rising cost of material handling, the changing demands on infrastructure, and the incompatibility of the workforce. Due to their budgetary limitations and strategic implementation of GSCM, Small and Medium Sized Enterprises are thought to be more hesitant to adopt GSCM (Rahman et al. 2020).

7.2.3.3 Lack of Awareness and Lower Demand from Costumer

The initial cost of green supply chain architecture may rise due to inexperience with handling green items. Professionals unfamiliar with GSCM procedures often overestimate the cost of GSCM structures. Due to the perceived reliability and cost-effectiveness of traditional supply chain systems, experts continue to use them in the face of this mismatch. Pakistani (Karachi) businesspeople are ignorant about environmental legislation and initiatives. It demonstrates the upper management's lack of enthusiasm for GSCM implementation. Additionally, GSCMs success is hampered by the management staff's lack of environmental understanding. Additionally, managers' inability to quickly address issues and come up with solutions to avoid incurring additional expenditures might hinder the growth of green businesses.

7.2.3.4 Inadequate Knowledge and Support

Implementing green initiatives in traditional supply chains requires a sufficient understanding of the concept and appropriate training and assistance. Implementing GSCM techniques might be seriously hampered by a lack of awareness of green practices. This has the effect of limiting employee skills and knowledge in creating customer awareness of green products.

Another major obstacle to the efficient and effective adoption of GSCM procedures is the lack of consumer knowledge of green products. Due to their ignorance of the significance of GSCM, Karachi's industrial sector's supply chain expertise accords comparatively less care and priority to environmental challenges. Many manufacturing businesses in Karachi continue to use the most antiquated technology, harming the environment (Nazam et al. 2020).

7.2.3.5 Business Organization

Another obstacle to adopting and implementing GSCM in Pakistan is the lack of appropriate environmental plans and planning (Karachi). However, to achieve its full potential, the organization must correctly assign coordinating tasks to people and departments at all levels and across all departments (Narayanamurthy et al. 2018). The findings reveal a significant obstacle in the form of carbon emissions, which are produced by diffuse sources across the supply chain and are not under the direct

control of any one organization. The current global supply chain is characterized by decentralization and interdependence, identified in the poll as the primary obstacles to effective business "greening" activities. Many organizations are stuck in the goal-setting phase at best. Most likely, businesses are hesitant to make their supply chains central to their sustainability initiatives since doing so would force them to work together on an issue that isn't a high priority for their supply chain partners or host nations.

However, honesty and open communication between program participants are crucial for sustainable results. For instance, businesses need to learn the ins and outs of their suppliers' procurement strategies and processes and the logistics involved in transporting raw materials and completed items across international boundaries. Suppliers typically see this form of due diligence as onerous, leading to more significant costs. Companies committed to creating greener supply chains should keep the following in mind when they interact with partners in the supply chain on ESG diligence issues and include environmental sustainability criteria into their overall partner certification and auditing procedures.

7.2.4 Analyze Current Supplier Partnerships

More and more frequently, businesses that worry about the reputational risks posed by their suppliers' activities in the supply chain are checking out their environmental profiles. Thirty-one percent of people who took the study said they had terminated a supplier because of its poor environmental record. When a supplier breaks the conditions of their contract, the firm often terminates them (Khan et al. 2021b). If a supplier's contract was terminated due to poor environmental performance, it was probably because the provider didn't meet any sustainability criterion (Baig et al. 2020). The study found that 51% of respondents monitored or assessed the green credentials of their suppliers. To include a supplier's ecological impact into the terms of an agreement, (1) a system to audit or quantify emissions production, and (2) basic environmental requirements are required.

7.2.5 Evaluation Methods

Tools are abundant at your disposal for assessing a provider's environmental performance. You may find several strategies for estimating greenhouse gas emissions in documents like the GHG Protocol Calculation Guidance (Aust et al. 2020). While some approaches require businesses to get information from their suppliers directly, others allow for secondary data (such as average industry information), which may not be as disruptive to the supplier relationship but may also be less accurate.

The disqualification of a provider is further complicated by the need to consider the host nation's regulations and regulatory issues and the accessibility of suitable

alternative suppliers. The survey findings show that legal systems and customs in host countries typically receive little to no attention. Companies risk breaking regulations in the nation where they source goods or services if they don't consider such rules.

China's new Anti-Sanctions Law (ASL), for instance, might hamper a business's development toward sustainability. The ASL gives China's government and businesses several options for retaliating against the United States and the European Union for trying to enforce regulations that China considers "discriminatory or restrictive." In particular, China is cognizant of environmental, social, and governance (ESG) initiatives enacted abroad but disadvantage Chinese businesses. A corporation should think carefully about the potential adverse ASL ramifications of discontinuing a supply arrangement with a business based in China before doing so.

Fortunately, corporations' efforts in this area will be aided by the increasing visibility of environmental sustainability challenges on a global scale, which will push ESG into the mainstream. For instance, when negotiating free trade agreements, environmental sustainability is becoming increasingly important. Chapter 24 of the United States-Mexico-Canada Agreement (USMCA) is devoted to environmental preservation, and all three countries must ensure that its provisions are followed. The World Commerce Organization (WTO) also focuses on the connection between global commerce and greenhouse gas emissions. Roadblocks may disintegrate as environmental, social, and governance (ESG) factors gain traction in international trade.

7.2.6 ESG Possibilities Expand with the Addition of New Suppliers

If an organization's present suppliers cannot fulfill the company's updated sustainability criteria, it may qualify possible new suppliers to take their place (Aust et al. 2020). Results show that 41% of those polled had chosen a vendor partly because of the company's commitment to environmental responsibility. Shifting sourcing to more sustainably-conscious suppliers may be difficult depending on the number of available alternative suppliers, production complexity, and the necessary regulatory approvals. However, new suppliers provide a clean slate to accomplish sustainable goals, unlike established supply partnerships that precede an organization's ESG initiatives. A corporation can issue Proposals (RFPs) requests with qualifying and ongoing compliance metrics and reporting requirements. A corporation may include audit criteria in its supply agreements at the commencement of a new supplier relationship to keep tabs on the supplier's ongoing sustainability initiatives (Ishizaka et al. 2023).

7.2.7 Downstream, There Are Direct Routes to "Greening" That Matter

In the supply chain, firms often have more insight into and authority over the downstream. With increased transparency and command, businesses can achieve their carbon targets better. For instance, the report details ways businesses may lessen the environmental effect of their goods by giving more thought to emissions during the design phase, which accounts for almost 80% of the total. It is entirely within the authority of businesses to implement design efforts that increase the durability of their goods and their potential for reuse and recycling. Those businesses who are genuinely committed to "greening" may find that modifying their product designs somewhat can positively impact their short- and long-term bottom lines. In addition, businesses can now pick service providers and logistics organizations that contribute to their sustainability objectives, giving them a more significant say in the movement and dissemination of their products.

7.2.8 The Effects of Global Warming

After recent severe environmental catastrophes like bushfires, floods, and earthquakes throughout the globe, there has been a significant increase in worry among governments and scholars regarding the effects of global warming. Air pollution, the most hazardous due to its quick penetrability and long-distance movement, has risen dramatically due to rising CO2 emissions (Mubarik et al. 2023). Vehicles and industrial processes are the primary causes of air pollution in developing countries. Large enterprises producing iron, steel, and petroleum, combined with airborne pollutants from smaller businesses and factories, are the primary causes of air pollution. Due to ineffective environmental protection policies, weak environmental regulations, and immature pollution control procedures, polluting industries can thrive in the developing world. Disposal of hazardous waste and other air, water, and land pollution devastates human health. The developed world is partly to blame for these environmental problems in developing nations since it paved the way for exporting its most polluting industries.

For example, scientists devised the phrase "pollution haven hypothesis" to describe how rich countries shift dangerous industries and technology to developing countries because of occupational and ecological dangers. Numerous academics and writers have examined the validity of the pollution refuge theory since its inception. While some scholars have raised concerns about pollution havens in many developing nations, others have argued that environmental benefits result from relocating industries from countries with high labor costs to those with lower labor costs because the relocated businesses bring cutting-edge pollution control methods. Green practices in the supply chain and increased focus on environmental issues have emerged as

a hot topics in both business and academics. The last two decades have seen environmental concerns in managing supply chains emerge as viable terrain and areas of action in their own right.

There appears to be a correlation between the growing public awareness of environmental issues, particularly global warming, and the efforts of governments and non-profits to mitigate their effects. The research patterns have led to practical ramifications as the developing nations of Brazil, Malaysia, Taiwan, and China have embraced GSCM. Research out of Taiwan suggests that green collaboration and internal execution of green performance initiatives have a favorable impact on firms' competitiveness. Similar results were found in a study of the Brazilian automobile industry, which found that encouraging supplier collaboration on environmental standards led to better overall performance for both firms and suppliers. Malaysia took its responsibility for the environment more seriously than other developing nations and embraced the finest green practices, making them perfect for the case study and providing a lead for future research in the industrial field. However, there is a lack of a concrete framework in the existing research on partnerships to help businesses work together to improve the environment throughout their supply chains.

7.2.9 Green Supply Chain Management

With the proliferation of environmental issues, countermeasures, and a heightened worldwide awareness of these issues, Green Supply Chain Management (GSCM) has emerged as a fruitful study area in recent decades (Zaman and Kusi-Sarpong 2023). Research on developing nations like Pakistan and Thailand is still sparse, even though the field of GSCM has been investigated and improved upon over time. In contrast to the richness in overall performance, there is room for more study of GSCM in the framework of corporate adoption strategy in the developing world. South Asia has become a significant hub for outsourcing manufacturing, but little research has been done on the implications of this trend for global supply chain management (GSCM). Multinational corporations have significant power to alter international supply networks drastically. This report suggests integrating environmentally friendly strategies for reducing pollution within the supply chains of major corporations to cascade these strategies down to their smaller competitors. As a result, the study establishes a theoretical framework that integrates green practices, collaboration motivations, and communication mechanisms to address the existing knowledge gap and reveal promising avenues for future research only possible through partnerships in the field of GSCM.

7.2.10 Multi-tiered GSCM Practices

By "green supply chain management practices," we mean "the incorporation of environmentally friendly issues across the supply chain woven into inter- and intra-organizational practices," as defined in this research. However, because our explanation variables are linked to GSCM activities within organizations, we focus primarily on GSCM activities inside a single organization. Sustainability scholars define GSCM as "the use of diverse resources in novel ways, making use of distinctive capabilities, to produce or implement a product or process to reduce green impacts." Global supply chain management strategies may impact every facet of a business, from research and development to logistics. The literature suggests that GSCM techniques improve businesses' long-term viability and bottom lines.

Both real-world and theoretical examples demonstrate how focal companies are held liable for green wrongdoing in their supply chains lower layers, regardless of whether or not they had any direct participation. The company suffers reputational harm and a drop in value due to this chain responsibility. If a company's primary suppliers misbehave, it will lose 1.00% of its shareholder value. Shareholder value is reduced by 1.13% when accidents are blamed on Chinese vendors. Companies must own the responsibility of the supply chain they operate and actively promote GSCM practices among those who are part of their supply chain, especially their lower-tier suppliers, to prevent further damage from being done by the media.

However, multi-tier distribution networks for GSCM management have only recently attracted academics' attention. A recent analysis of the GSCM literature confirms this tendency by showing that most previous research has been conducted from a downstream perspective. It's undoubtedly tricky for focal companies, especially when managing supply chain partners lower down the food chain. Numerous studies show that these companies keep an eye on the environmental practices of their direct suppliers, yet many don't put the same standards on their own (second-tier) vendors. As a result, expanding GSCM outside the confines of a single company continues to be a hot issue in academia and industry alike.

7.2.11 Customers' Demands and Vendors' Ability

According to the research, consumer demand and supplier capability are the two most essential factors in GSCM practice implementation. Many studies have used stakeholders and institutional theory to stress the significance of external pressure from stakeholders to adopt GSCM practices. The salience of the stakeholder reflects the stakeholders ability to state the claim, the legality of its activity, and the urgency with which the focus businesses must address the claim. Firms' adoption of GSCM practices has been connected to green pressure from consumers, who represent the most significant stakeholder with each characteristic. As a result, a mountain of proof

supports the claim that consumer pressure is directly linked to implementing GSCM strategies.

In a multi-tiered supply chain, stakeholder settings and importance can vary greatly. Previous research has underlined the importance of supplier-related factors in determining the extent of the reaction to stakeholder pressure along the supply chain, particularly consumer pressure. Businesses in business-to-customer industries (somewhat downstream) had higher GSCM involvement than those in business-to-business sectors (somewhat upstream). When characteristics like a supplier's reputation and generosity contribute to a higher degree of trust, this distinction becomes even more pronounced (Zaman and Kusi-Sarpong 2023).

Typically, smaller, more obscure businesses make up the lower tiers of a supply chain. These businesses are often less vulnerable to stakeholder demands, such as laws and regulations, than more giant corporations. Therefore, businesses build a wide range of green skills in response to the demands made on them at various stages of the supply chain. Even suppliers lower in the supply chain are subject to this rule. The green efforts taken by these suppliers have been documented in several GSCM studies and are thus necessary for the widespread implementation of GSCM principles across the supply chain. The lack of research on the relationship between customer demand and supplier capacity for various GSCM adoption patterns may be a barrier to 'green contagion' throughout different stages of the supply chain.

Although there has been a focus on GSCM adoption in the multi-tier supply chain, the most severe violations still occur in the supply chain upstream, above the upstream and first-tier levels (Foerstl et al. 2015; Wilhelm et al. 2016a; Kim et al. 2019). We reiterate our claim that insufficient uptake of GSCM procedures through the supply chain is to blame for this problem. Therefore, the research needs a more nuanced understanding of the complexities that influence adopting GSCM methods throughout complicated multi-tier supply chains. In this study, we add to this growing body of research by investigating the differential impact of supplier capabilities on GSCM adoption in reaction to consumer demand, especially among small and large businesses.

7.2.12 For What Reasons Do Businesses Choose Eco-friendly Supply Chains?

While the original intent of GSCM was to improve environmental sustainability, several businesses have begun using it as a promotional tool. Several large environmental groups, institutions, and organizations have emerged due to the public's growing concern about sustainability and climate change. Therefore, more and more people are choosing not to buy non-sustainable goods. Therefore, businesses are jumping at the chance to employ GSCM principles to boost their image and customer satisfaction. They can reach a wider audience, boosting sales and exports to environmentally conscious nations.

Certain firms have even linked sustainable business practices to bottom-line improvements. For instance, GM saved $12 million on disposal fees by instituting a reusable container with its vendors. GSCM may be used in nearly any manufacturing company. The first step in implementing this idea is to analyze the present supply chain and pinpoint places where sustainable practices might be included. Improved recycling and compostability of packaging are two examples of how cleaner material sources may benefit stores. Materials suppliers who practice ecologically sound sourcing practices are another option for businesses. Reducing carbon emissions from shipping and delivery can partially be accomplished by purchasing supplies from local businesses. In addition, some businesses could lower their carbon footprint by switching to greener transportation methods and fuels (Zaheer et al. 2023).

Through logistics optimization, businesses may lessen their impact on the environment by decreasing the number of miles their goods must travel and the number of empty miles their trucks must travel with. Companies should avoid working with vendors that distribute illegal goods by requiring them to have appropriate certificates before doing business with them. A manufacturing firm, for instance, may opt to work exclusively with LEED-approved vendors to purchase raw materials.

7.2.13 Strategic Human Resource Management: Why It Matters

For businesses to succeed, SHRM is crucial. Organizations may benefit from SHRM's guidance by improving employee performance, training and developing their staff, and fostering a pleasant work environment via strategic HR planning and implementation (Jamil et al. 2022). By lowering attrition and raising productivity, SHRM can help organizations save money. Organizations can benefit from SHRM's ability to assist in developing systems to monitor and enhance employee performance. SHRM may aid firms in workforce development by assisting in identifying employees' development needs and providing training and resources to meet those requirements. Positive work environments result from well-managed employee interactions, which SHRM can assist companies in achieving (Si et al. 2023).

SHRM may assist firms in reducing turnover by assisting in developing pay and benefits plans that are attractive to and retain key personnel. The Society for Human Resource Management (SHRM) may aid organizations in increasing output by fostering higher levels of employee performance and satisfaction in the workplace. It is essential to implement the SHRM strategy now that you have established corporate goals, anticipated future requirements and collected the necessary resources. Most businesses begin with finding qualified individuals, then move on to training and development, and finally, performance management. However, the precise figure will change based on the requirements of your business (Jiang et al. 2023).

If you have a big pool of qualified applicants, you may invest in the professional growth of your present staff before looking elsewhere. You may still need

to add to your team after exhausting that option. If so, you should know exactly what you want and what skills they must have before you start looking for candidates. It is crucial to have an effective onboarding procedure in place once you have acquired talent. This will assist your new employees in feeling welcome and prepared for their roles. Once new hires have been made, it's time to put effort into their growth. Opportunities for training and advancement in one's career are included. You can keep your best employees happy and productive by giving them these chances. Management of performance comes last. Among these include the use of performance appraisals, feedback, and the establishment of specific expectations. To make sure your employees are living up to your high standards and adding value to the business, performance management is an integral element of SHRM.

7.2.14 When Putting Your SHRM Strategy into Action

Establish attainable objectives and timeframes. Attempting to cram too much into too little time increases the likelihood of making mistakes. Obtain management's approval of the plan. Getting everyone staying on with your SHRM strategy will be challenging if the top brass isn't enthusiastic about it. Get the word out to your staff. The SHRM plan's aims and how they will influence employees should be communicated clearly. This will assist in bringing everyone on board and guarantee they are all pulling in the same direction. Prepare to make changes to your strategy. Any strategy has the risk of failing for a variety of reasons. Adjust your course as needed to ensure your organization is still on track to succeed.

7.2.14.1 Verify and Adjust

It is essential to evaluate progress after putting your SHRM strategy into action. This involves analyzing the successes and failures thus far. Your evaluation may suggest some changes to your strategy. For instance, if your current recruitment efforts aren't yielding the desired results, try something new. Alter your training methods if you realize they aren't producing the desired results. Don't forget that your SHRM strategy is an ongoing process. Your company's human resource management (HRM) demands will evolve and expand over time. That's why it's crucial to check in on your SHRM strategy occasionally to ensure it's still serving you well.

To reach their objectives, businesses can benefit from strategic human resource management. With the help of a well-thought-out SHRM strategy, businesses can better recruit and retain the talent they need to succeed. The effort spent on creating an SHRM strategy is time well spent. You can retain top talent and keep your employees interested in their job with a well-executed SHRM strategy, which will help you reach your company's goals. Companies have a way of developing a character all their own. Most HR professionals would agree that the culture of a business is just as much a reflection of its character as it is of the way it does business. A company's culture

may spiral out of control if left to its own devices. The worst-case scenario is that it causes low morale and a high employee turnover rate. The HR department may make a company's culture more cooperative, helpful, and less poisonous.

7.2.14.2 Collaborate with the Chief Executive Officer

The CEO is the conduit via which the company's culture is infused. Human resources should collaborate with the CEO and receive the same respect. Ecologically sound societies are prosperous and submissive. Recognition of inclusion and diversity is an integral part of compliance requirements, and as such, the organization's values, beliefs, and goals must align with them. Human resources professionals may aid in navigating such challenges to assist and cultivate a strong culture.

7.2.14.3 Culture-Fit Interview

Fit with the company's culture may be evaluated during the interview process. Behavioral competence questions that align with and support the company's fundamental values, purpose, and vision statements are excellent tools for doing this. This is a method of being proactive and purposeful in your search for compatibility.

7.2.14.4 Crucial Modeling and Reinforcement

Many employees in companies with solid cultures exhibit certain traits or customs. Human resources should model these behaviors and assist managers in spotting instances where team members are not doing so. The next step is to collaborate with the supervisor to coach the employee to exhibit the desired behaviors.

7.2.14.5 Put Your Employees' Worth on Display

Employees want an organization with a culture that shows they are respected and appreciated. Human resources departments should implement attitudes and programs encouraging and motivating such conduct. Better productivity, fewer turnover, and more invested employees all stem from fostering a positive business culture. There will be happier customers as a result of this.

7.2.14.6 Line Up the Group

Engagement among workers surveys are an excellent and economical tool to learn how workers feel about the company's culture. This type of input may be invaluable in helping HR leaders determine if they are headed in the right direction or need

to make some adjustments. Asking workers for their input may do wonders for the morale of an organization.

7.2.14.7 Encourage an Atmosphere of Deference

Every thriving business has one thing in common: a culture based on mutual respect. Everyone in the company, from the CEO down, should treat workers with dignity and respect. Human resources could show appreciation for their workers by responding quickly to employee concerns and complaints. When leadership treats employees with dignity and fairness, morale and productivity soar.

7.2.14.8 Establish a Group Made Up of Workers

We actively engage in this; as individuals, we are developing, and as a result, our collective culture is also evolving. Having a committee of employees allows me to foster our company's development by engaging in open dialogue with my colleagues on how we can improve the working environment for all employees. Limit the team size, hold frequent meetings, and focus on improving the team's health, morale, and productivity.

7.2.14.9 Plan Your Approach to Listening

Create and implement an in-depth method of active listening. Culture is something about which everyone has an opinion but about which only the consensus of the workforce should count. To learn how workers feel about the current culture and to collect their thoughts on what can be changed to prepare for the future, it is essential to go beyond the yearly engagement survey and implement more of an "always-on" feedback mechanism.

7.2.14.10 Involve and Diversify

Human resources departments can't afford to ignore business culture to support administrative details. Human resources can build a strong team by recruiting a wide range of people who all value the same things. Human resources departments may create engagement initiatives to help employees feel more connected to the company, conduct surveys to gauge employee satisfaction and provide workers opportunities to explore further and develop the firm's core values.

7.2.14.11 Celebrate Successes

We let too many weeks and months pass without praising workers' efforts. Make sure your staff knows that their hard work has been seen and appreciated, and take the time to explain the reason they are getting honored. In addition to boosting morale and company culture, this method of expressing gratitude is also long-lasting.

7.2.14.12 Create Connections

When workers know they will interact with individuals they like at work, they are more likely to anticipate coming to work. Having a positive outlook on the job is easier for them when they treat their coworkers like friends. Because of this upbeat outlook, workers can better interact with one another and rely on and trust one another. In a nutshell, when they collaborate, they multiply their productivity.

7.2.14.13 Maintain Open Lines of Communication

Human resources should serve as a conduit for organizational culture, but that culture cannot originate there. The tone and defining characteristics of a company's culture are best reflected in the words of its top executives. These are to be in sync with goals and principles declarations but go beyond to bring them to life via relevant instances. All staff members should have an opportunity to contribute so they may take pride in spreading the word.

7.2.14.14 Make People Take Responsibility

HR has the power to enforce accountability for culture among both management and employees. Discordant actions should be pointed out as such. Human resources should also recruit personnel who uphold the company's principles and culture (Khan et al. 2022a).

7.2.15 Sustainable Consumption and Production

Sustainable consumption and production may benefit from cutting-edge scientific and technical advances, which can be leveraged by implementing GSCM principles. Has the implementation of GSCM methods affected environmentally friendly production and consumption? This question should be asked in this context by companies to sway the goal of CEOs and upper management to embrace the GSCM practices. If so, why would it be the case? How does implementing new technology affect a company's bottom line? This study seeks to address these concerns scientifically,

aiming not only to elucidate why the adoption of GSCM practices boosts companies' output but also to suggest policy measures that will aid the adoption of GSCM procedures by SMEs in Pakistan. Manufacturing SMEs can benefit economically and ecologically from GSCM and clean, innovative technology (CIT) because of the rising prevalence of globalization. Energy savings and productivity gains in business are just two outcomes of GSCM and CIT implementation. It's also essential for the growth of things like green innovation, environmental sustainability, and better supplier-customer relationships. Sustainable manufacturing SMEs may be fostered through the use of GSCM and CIT (Nafees et al. 2021). Despite the growing acceptance of GSCM and CIT in many nations, there are still challenges to be overcome. In addition, whereas previous research has concentrated chiefly on large companies, we looked into the possibility of GSCM and CIT adoption in the context of small and medium-sized manufacturing businesses.

7.2.16 Profitable Endeavors

Profitable endeavors, forward-thinking company growth, positive environmental effect, and the creation of successful businesses are all greatly aided by the use of GSCM and CIT. Several businesses are incorporating environmental and supply chain management techniques to boost their long-term competitiveness via GSCM. Implementing GSCM and CIT substantially affects the performance and product development of businesses because they offer additional benefits and affect cooperative relationships with internal and external suppliers and consumers. Increasing the effectiveness of a business, green supply chain management also benefits the company's CIT and sustainable production (Li et al. 2020). GSCM and CIT are beneficial because they promote business growth, lessen environmental impact, and raise output and consumption. Zaid et al. (2018) reviewed much research that finds a clear correlation between GSCM and CIT adoption. The adoption of GSCM and CIT for sustainable production and consumption is influenced by numerous elements in the manufacturing business, including consumer knowledge, quality of resource management, stakeholder pressure, and government assistance (Si et al. 2023).

While research on the spread of GSCM and CIT has been conducted in several developed nations, there is still a knowledge vacuum regarding emerging nations like Pakistan. Research into the connection between GSCM and CIT is limited and often overlooked in Pakistan. Organizational environmental management, green consumerism, and cooperation with suppliers are only a few of the narrow topics already covered in the literature. To the best of our knowledge, this is the first study of its type to investigate the factors impacting the decisions on GCSM for manufacturing SMEs in Pakistan. The primary goal of this research was to determine what elements are most important for small and medium-sized manufacturers in Pakistan to implement GSCM and CIT successfully. This research will fill a knowledge gap by determining the elements CEOs believe will be most influential in their decision to use GSCM and CIT. Last but not least, this research gives decision-makers a better

grasp of the GSCM adoption process and how to better assist SMEs in implementing CIT.

7.3 Methodology for the Book Chapter

There are two main sections to the book chapter. In the first section of the study, we theoretically defined GSCM and discussed the barriers that prevent GSCM activities in Pakistani manufacturing enterprises (Karachi). The second component of the study, however, relies on conducting interviews. Interviews are done with supply chain management experts who have held high positions in various firms. Experts have posed a semi-structured question. Despite being in good positions, we discovered a lack of knowledge and awareness about green supply chain management as interviewees could not provide adequate knowledge about the GSCM concept. As these studies are new in Pakistan, the lack of awareness ultimately results in lower customer demands, and it can also be considered as another significant factor that hinders (Karachi).

7.3.1 Approach for the Book Chapter

The study methodology uses grounded theory to investigate the barriers to GSCM practices in manufacturing organizations in Karachi. To demonstrate rigor and credibility, the emphasis is on showing how the facts obtained connect to the emergent theory. Six semi-structured interviews with experts from five manufacturing businesses were performed in total. The East African-based Momin Group of Companies, Procon Engineering (Pvt) Ltd, and Artistic Millionaires Pvt. Ltd. are examples of manufacturing companies that have successfully established themselves in Karachi.

7.3.2 Themes

Transcriptions of interviews have been done in Table 7.1 using the exploratory approach; this book chapter consists of 6 transcriptions from supply chain management expertise. Different themes have been developed, and a storyline is created to make sense of the volume of rich text by manually coding key elements of interviews.

Table 7.1 Categorization of coded themes

Theme	Vocal#1	Vocal#2	Vocal#3	Vocal#4	Vocal#5	Vocal#6	Comments
Understanding GSCM	Vast term/demand ideal system	Integration with suppliers	Reduction of unhealthy elements		Merging durability	–	Respondent explained the understanding of GSCM
Ground realities	Ideal system smooth path	Acceptance is hard	New policy or practice is always a tricky task	Old supply chain management, one time cost	Negative impact or affecting business	Seetha system in organization/ family business	Interviewees have highlighted the different ground realities that impede the adoption of GSCM Practices in Karachi
Mentality and cultural aspects	Old mentality, Rigid, Resist change	Non-improving attitude within the seniorities and authorities	Old policies, lack of loyalty, Reluctant to take risk	Strong Reference system	–	Old mind resists new changes	Interviewees emphasized on major mentality and cultural aspects that are being commonly practiced in Kci organizations
Financial instability	Huge amount required	High-cost goods	Economy hurdles	Short term planning	Financial up strains	–	6 out of 4 responded have focused on financial up strains

(continued)

Table 7.1 (continued)

Theme	Vocal#1	Vocal#2	Vocal#3	Vocal#4	Vocal#5	Vocal#6	Comments
Unskilled workforce	Training of employees	Skilled labor is required	Lack of responsibilities by of higher managements	–	Backward in technology	Focused on revenue and profit scale	All of the respondents outlined the lack of responsibility and awareness as hindrance in the adaptation of GSCM
Implementations	Partially implemented	Initial stage	New concept in context of Pak	Not 100%	–	–	Respondent agreed that GSCM is new concept in Pak and organization in Kci are not fully implementing GSCM practices
Govt policies	Govt is taking initiatives for diminishing unfavorable natural impacts of industries	Grow trees initiative by PM IK	Plans for counter are still disclose	Strong legislation/ role of fed govt	Green housing	–	All respondent mentioned that govt is playing positive role to counter un healthy elements from environment

Source Author

7.3.3 *Practical Implications of GSCM in the Manufacturing Sector of Karachi*

The articles examined offered a few logical recommendations for senior management and authorities. Karachi's manufacturing sector's supply chain management may have an ecological impact by implementing functional modifications, such as eco-plan, by following environmental standards (Nisar et al. 2021). (Gholami et al. 2016) recommended adopting approaches that include closed-loop systems and reuse. This study aims to explore the theoretical and practical implications of implementing green supply chain management (GSCM) in the manufacturing sector of Karachi.

The intersection of supply chain management and sustainability has garnered increased attention among developing nations in recent times. GSCM is a derivative of the aforementioned research domain. The emergence of environmental sustainability concerns has become a crucial node in the face of challenges encountered by traditional supply chain processes. The evaluated research works have identified recommendations for executive leadership and policymakers in the manufacturing industry. The implementation of Green Supply Chain Management (GSCM) can yield significant environmental benefits by means of strategic and operational modifications. This is particularly relevant in the urban center of Karachi, which serves as a notable industrial center in Pakistan (Khan et al. 2022b).

The objective of Green Supply Chain Management (GSCM) is to integrate ecologically sustainable practices into supply chain operations, with the aim of mitigating the adverse environmental impacts of business activities (Mubarik et al. 2021). The implementation of a Green Supply Chain Management (GSCM) framework that encompasses various elements, such as an environmentally sustainable plan that aligns with global ecological benchmarks, could potentially yield advantages for Karachi's industrial domain (Nisar et al. 2021). This measure could facilitate compliance of businesses with global environmental regulations and promote the development of a corporate ethos that places a premium on environmental conservation.

In essence, an eco-plan refers to a comprehensive strategy comprising of objectives and actions implemented by an organization to enhance its ecological sustainability over an extended period. Energy conservation, waste minimization, and material recovery through recycling are all illustrative instances of potential actions that could be implemented. One potential approach for manufacturers to mitigate their environmental footprint is to adopt energy-efficient technologies or transition to less polluting manufacturing techniques (Khan et al. 2022c). A comprehensive ecological plan will delineate the measures required to achieve the organization's sustainability objectives while avoiding any adverse effects or even enhancing the organization's financial performance.

The adoption of closed-loop systems represents an alternative approach, as suggested by Gholami et al. (2016). The phrase "closed-loop system" is employed within the domain of supply chain management to denote the procedure of encompassing all phases of a commodity's existence, commencing from the procurement of

basic materials to the ultimate disposal. This configuration enables the manufacturer to engage in the practice of product or component recycling upon their attainment of their intended use.

For the implementation of such a system in Karachi's manufacturing industry, it would be imperative to prioritize the reusability of materials and products. Consequently, there is a possibility of observing a rise in practices such as product refurbishment and recycling, which aim to transform waste into a valuable commodity. The implementation of industrial practices that prioritize the efficient utilization of resources and the minimization of waste would lead to the establishment of a circular economy (Khan et al.).

For the successful implementation of such plans, it is imperative that the executive leadership and policymakers in Karachi's industrial sector comprehend the significance of GSCM. The adoption of this approach could be perceived as a means to enhance operational efficiency and economic feasibility, while also serving as a remedy for environmental sustainability. An optimized Green Supply Chain Management (GSCM) model has the potential to generate cost savings through various means such as waste reduction, improved resource efficiency, enhanced brand reputation, and regulatory compliance. Additionally, it may foster creativity among stakeholders. Consequently, it possesses the capability to confer a competitive advantage to enterprises in the current era of globalization and heightened environmental awareness.

Establishing an environment that fosters and facilitates such practices is imperative for fully realizing the potential of Green Supply Chain Management (GSCM) in the industrial sector of Karachi. Potential measures to encourage the adoption of Green Supply Chain Management (GSCM) could encompass various strategies, such as fostering research and development endeavors and incentivizing corporate entities to integrate GSCM practices into their operations. Additionally, establishing robust recycling and waste management infrastructure could also be a viable approach to promote sustainable practices within the supply chain.

To conclude, the implementation of Green Supply Chain Management (GSCM) could potentially lead to significant advancements in environmental sustainability within the industrial sector of Karachi. The implementation of strategic and functional modifications, such as the adoption of an eco-plan and closed-loop systems, may enable the industry to mitigate its adverse environmental impact, enhance its operational efficiency, and improve its competitive positioning in the global market. Nonetheless, the realization of GSCM can solely be achieved if the leadership and policymakers of the industry are in agreement with and fervently support the concept.

7.4 Implications of the Book Chapter

The following study implications are produced in light of the book chapter mentioned above chapter findings and based on interviews with supply chain industry professionals. Prioritizing the most critical hurdles and developing policies to address them

are highly useful for the stakeholders in creating pollution-free, socially responsible, and economically favorable policies and encouraging businesses to embrace green policies by assisting them in converting their existing supply chains into green ones (Zaman et al.). Modify your methods to lower your import bill because Pakistans import bill is rising daily, causing a decline in the export of goods stamped "Made in Pakistan for many years. Adopting supply chain efforts in producing sanitary products is one of the essential strategies that need to be focused on to address this critical position of Pakistans economy (Nazam et al. 2020).

7.4.1 Recommendations

This study can give managers, stakeholders, and supply chain experts insight into Karachi's industrial organizations' challenges while implementing GSCM techniques. Additionally, this book chapter might inspire relevant authorities to share their experience to develop crucial designs for implementing GSCM methods in Karachi's manufacturing sectors.

7.4.2 Model Representation of Barriers to GSCM Practices in Organization

Graphical representation of the model has described the relationship of barriers towards GSCM with multiple factors that have hindered the adaptation of GSCM in the manufacturing sector of Karachi. This model also explains the impact of each barrier directly connected to the hindrance of GSCM (Kaur et al. 2018). The articles examined offered a few logical recommendations for senior management and authorities. Karachi's manufacturing sector's supply chain management may have an ecological impact by implementing functional modifications, such as eco-plan, by following environmental standards (Nisar et al. 2021). Gholami et al. (2016) recommended adopting approaches that include closed-loop systems and reuse.

7.4.3 Insights and Implications Post-Covid Practice

As seen in Fig. 7.1, the following study implications are produced in light of the book's above chapter findings and based on interviews with supply chain industry professionals post covid. Prioritizing the most critical hurdles and developing policies to address them are highly useful for the stakeholders in creating pollution-free, socially responsible, and economically advantageous policies. Encouraging businesses to embrace green policies by assisting them in converting their existing supply

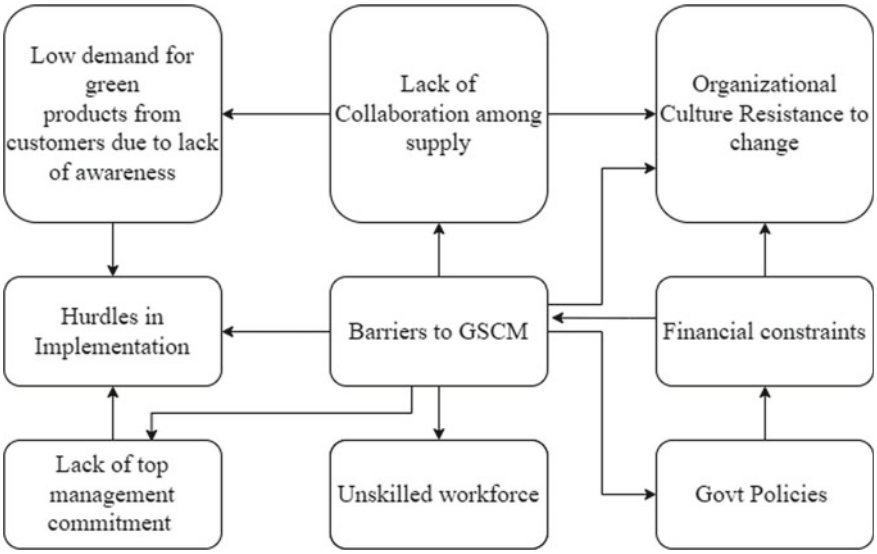

Fig. 7.1 Graphical representation of the model. *Source* Author

chains into green ones (Khan et al. 2023b). Modify your methods to lower your import bill because Pakistans import bill is rising daily, causing a decline in the export of goods stamped "Made in Pakistan for many years. Adopting supply chain efforts in producing sanitary products is one of the important strategies that need to be focused on to address this critical position of Pakistans economy (Nazam et al. 2020).

7.4.4 Advantages of GSCM

GSCM is the term used to describe possibly incorporating environmental considerations into supply chain management linked to company performance. The adoption of GSCM procedures responds to the widespread interest in participating in environmentally friendly activities that might enable businesses to lower the cost of raw materials and packaging (Podgorodnichenko et al. 2020). Utilizing recycled materials will increase profitability for businesses implementing GSCM activities, enhancing their performance. By delivering environmental protection solutions, businesses using CSGM may satisfy consumer demands and gain a competitive edge through improved supply chain performance (Lin et al. 2020). Additionally, GSCM implementation reduces resource waste and lowers energy consumption, which supports societal and environmental sustainability. The economy's performance can be enhanced through sustainable social and environmental practices.

7.5 Conclusion

Due to increasing demand from national and international organizations, GSCM practices are becoming more prominent in many manufacturing industries. The manufacturing industry has started implementing green supply chain techniques in their conventional supply chains. GSCMs are widely used in industrialized countries. The Karachi industrial sector is taking steps to integrate environmentally friendly practices throughout its supply chains. Karachi's manufacturing sectors are dealing with various problems when implementing GSCM practices since there hasn't been enough investigation and study into the many barriers and hurdles that prevent the efficient execution of GSCM practices.

The manufacturing sectors in Karachi are happy to utilize environmentally harmful products and procedures, which does have significant economic repercussions, also because of a lack of environmental understanding of green concerns. Previous studies have demonstrated that by using GSCM procedures, companies become more wholesome. To protect the environment, the government should also adopt specific policies to make organizational operations more environmentally friendly, such as tax rebates, allowances, and training on the environments safety. As a result, management must train their employees to work with less waste. Every interested party must do its part for GSCM procedures to be implemented effectively if we are to safeguard the environment (Bombiak 2019).

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Chapter 8
Improving Supply Chain Resilience with a Control Tower Approach Beyond Covid-19

George Bennett, Andreas M. Radke, Hamid Moradlou, and Hendrik Reefke

Abstract Covid-19 caused major supply chain disruptions around the globe. Whilst many companies have been improving supply chain resilience over the years, not all companies were able to manage these disruptions successfully. Investments in control towers (CTs), as a potential solution, were insufficient. In this chapter we analyze the different types of CTs and the challenges in implementing them. This indicates that not all CTs provide adequate visibility and may not support the execution of mitigation options effectively. We present interviews with four companies to tie the literature review to industry practice, analyze the responses and discuss the results. We found that the theoretical scope of CTs is broader than supported in practice, implementation challenges pose an obstacle to effective leverage of the provided visibility and propose steps to raise the untapped potential benefits. In conclusion, we call for further research about CTs and supply chain design making frameworks, particularly the need to tie CTs to business processes and organizational design. As part of the summary, we discuss the limitations of our research in terms of availability of academic literature around CTs, the small number of interview use cases to draw more granular correlations.

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Keywords Supply chain resilience · Control tower · Visibility · Business process orchestration · Business process automation · Disruption management · Multiple case interviews · Covid-19

8.1 Introduction

While manufacturing companies had been greatly impacted by the Covid-19 pandemic in terms of demand, logistics and supply (Grida et al. 2020), with dramatic effects for some industries, the functioning of their supply chains was also critical—in some cases vital—for consumers (Esper 2021) and the involved and intertwined supply chain partners (Ivanov and Dolgui 2020; Sheffi 2020; Verschuur et al. 2021). Approaches to improve supply chain resilience strategically and structurally have been available before the start of the pandemic in 2020 (Hoek 2020), and operational approaches have been presented on a case-by-case basis (Aldrighetti et al. 2019; Butt 2021).

Yet, surveys of practitioners—published (Cecere 2021), and unpublished from client experiences—supported by subsequent research on future research directions for supply chain management and Covid-19 (Hoek 2020) indicate that certain operational aspects had not been fully understood: visibility has to sufficiently inform decision making and decisions have to be executed in a timely manner via business processes that control the supply chain.

In this chapter, we will first present a literature review of the motivation for resilience and disruption management, as well as visibility and control towers (CTs) as enablers thereof, followed by the need to revisit business processes. We then present the methodology for our research as well as the findings from multiple interviews with industry practitioners and their respective CT implementations. In our analysis we discuss these to the running, implementation, usage of CT, the challenges for successful implementation and the links to business process orchestration. We close this chapter with a summary and a research outlook derived from the limitations of this work.

This chapter responds to the call for further research in managing disruptions, collaboration across the supply networks, sustaining business operations and countering the effects of pandemics (Erboz et al. 2023; Queiroz et al. 2022).

8.2 Literature Review

8.2.1 Resilience and Disruption Management

Despite regional differences in the impact of Covid-19 on supply chains, common disruptions exist (Seuring et al. 2022) indicating that supply chain resilience, generally, supported the disruption mitigation. Supply chain resilience is the result of deliberate actions which increase flexibility and adaptability to prepare for unexpected events, that is risks, affecting business performance, so that the supply chain can respond to disruptions and, ideally, maintain continuity of operations (Ponomarov and Holcomb 2009). The gained flexibility and adaptability support regular operations, and because better preparation for disruptive events enables faster recovery than competitors, supply chain resilience is considered a competitive advantage (Sheffi 2005).

The moment a risk materializes it becomes a disruption and the impact on business performance, like revenue, cost-to-serve, customer service levels and so on. Disruption response is then the activity to manage the materialized risks (De Souza 2017).

Disruption response profiles can be identified by the effectiveness of preparational and operational levers on the duration and depth of a disruption on business performance, Fig. 8.1. The four levers are: (1) act to either delay the disruption impact, or (2) act to reduce the disruption duration, or (3) speed up the recovery, and (4) contain as far as possible the disruption severity (De Souza 2015).

Identifying the most effective options for each lever requires effective decision making (Ivanov and Dolgui 2020; Kumar and Sharma 2021). The development of

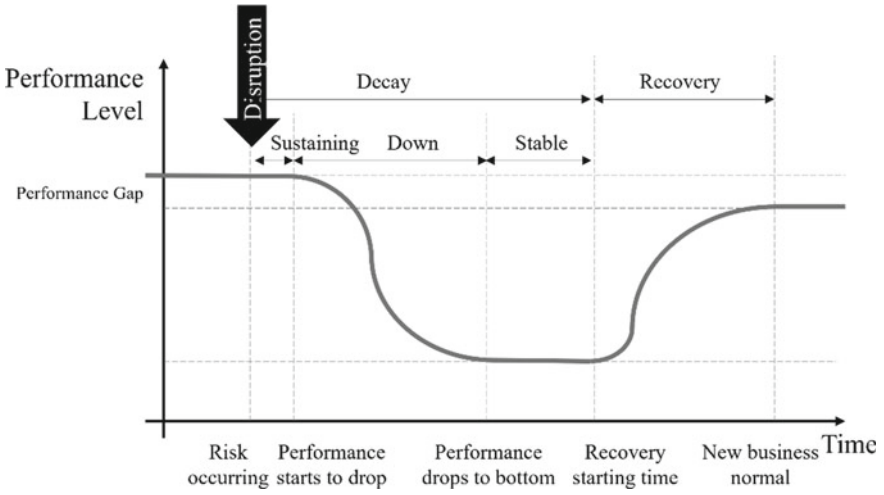

Fig. 8.1 Phases of disruption response (De Souza 2017)

options leading to recovery requires reliable, up-to-date visibility. However, once an option has been decided upon, the option has to be executed through quick business processes before the option or the preference of options changes (Sheffi 2020). Literature on visibility and quick action will be reviewed in the following.

8.2.2 Visibility Through Control Towers

CTs have been desirable in supply chain management by promising to enhance visibility and thus greater flexibility through cross-functional and organizational collaboration, greater external flexibility to meet demand is possible (Williams et al. 2013). By integrating data on a demand and supply level with market conditions, a full picture can be created for the supply chain of what the customer requires, will require in the future and how the focal company will meet those requirements enabling flexibility for creating new products, changing the volume of the output, the variety of products and modification to the product.

To achieve this level of visibility, companies must substitute technology for labor through the development of suitable information technology (IT) systems (Somapa et al. 2018).

Rai et al. (2012) describe supply chain visibility IT functionality as:

1. Detailed view of inventory throughout the supply chain with track and trace of shipments between supply chain partners at a granular level.
2. Integration with supply-side partners for real-time data on inventory levels and flow of goods through the business process, e.g. planning, production, shipment, distribution, and storage.
3. An exception-driven alert system that spots disruptions and potential disruption passing on the alert through the supply chain as required.

One of the key functions of a supply chain control tower (SCCT) is the ability to consolidate data from internal and external data sources, such as Transport Management Systems (TMS), Warehouse Management Systems (WMS) and Enterprise Resource Planning (ERP) software internally to the business, but also externally such as partner systems, live traffic feeds, political unrest developments and weather (Alias et al. 2015; Brintrup 2021; Handfield et al. 2020; Hofman 2014; Souza et al. 2020; Trzuskawska-Grzesińska 2017; Verma et al. 2020). This data is pulled together and orchestrated, allowing a single unit to be traced and linked throughout each system in the supply chain (Yan et al. 2012), acting as a hub in the supply network (Hui et al. 2014).

By orchestrating data, the SCCT can provide the user with real-time visibility enabling users to identify disruptions (Hofman 2014). A common term used in literature is single-point-of-truth, which describes how relevant information can be found in the CT, allowing users to collaborate and make informed decisions across multiple partners (Chen et al. 2018). The potential and actual outcomes of decision options

and actions taken from the CT will be shared with all relevant partners allowing each to know 'what happens, when and why' (Chen et al. 2018).

The user is provided information and insights in an easily digestible way related to their job function in the company. For example, Hofman (2014) states that the business planner would receive real-time data and exceptions to handle, whereas operations staff would be given physical actions to execute. Additionally, data is prioritized by urgency and impact through data visualization within the CT to prevent overwhelming the planner by vast amounts of unsorted data (Alias et al. 2015). A process called exception management, where parameters are set for each data feed, enables the system to identify when the values leave acceptable ranges becoming a deviation (Alias et al. 2015; Verma et al. 2020). Once triggered, recommendations for correcting the deviation are proposed to the user (Alias et al. 2015; Topan et al. 2020; Trzuskawska-Grzesińska 2017), with a digital playbook deciding which option should be recommended depending on the trigger and expected impact. SCCTs integrate company-internal and external data feeds to control planning (supply and demand planning) and execution of these plans (Vendor 2, 2019).[1] For the above-mentioned reasons, exceptions management and recommendations enable the SCCT to provide decision support across all data sources.

At the execution level, the SCCT can carry out a limited number of automated decisions across the functions. Topan et al. (2020) provide a detailed list of example actions used by original equipment manufacturers (OEMs) to intervene at the execution level (Table 8.1).

There has been a heavy focus on the use of artificial intelligence (AI) and machine learning (ML) in driving the decision support capabilities in the CT. AI is the broader concept of machines being able to carry out tasks in a way that could be considered "smart," while ML is a subset of AI that focuses on the ability of machines to automatically learn and improve from experience without being explicitly programmed. However, in the application in CTs this technology is still in its infancy stage (Verma et al. 2020), and thus applications should be modular rather than full-scale adoption at this point (Liotine 2019). The analytics engine focuses on four layers of increasing analytic value: Descriptive, Diagnostic, Predictive, and Prescriptive Analytics (Delen and Zolbanin 2018):

- At its most basic level, descriptive analytics identifies relationships in the data. This can come in the form of classification trees, k-neighboring or k-mean clustering, for example (Liotine 2019).
- Diagnostic analytics uses more advanced data analysis to explore the information further, aiming to derive causality using data visualization, data discovery and reporting.
- Predictive analytics uses algorithmic modelling to create as-close-to reality forecasts as possible with data mining; (Liotine 2019) adds regression analysis and time series analysis to the examples.

[1] Academic literature on SCCTs is sparse and is complemented by practitioner literature from anonymized vendors about their product offerings. The actual names and grey literature of vendors 1 and 2 are available from the authors.

Table 8.1 Intervention examples (Topan et al. 2020)

Intervention	Actions
Stock reallocation	Proactive stock reallocation from upstream
	Reallocation of returned parts
	Disposing parts
	Skipping regular replenishment
	Dynamic inventory rationing
	Backorder clearing
	Reallocation of a reserved part for preventive maintenance
Expediting	Emergency shipment from upstream (reactive)
	Emergency shipment from upstream (proactive)
	Lateral transshipment (reactive)
	Lateral transshipment (proactive)
	Expediting parts in repair
	Priority scheduling of repair jobs
	Expediting a new buy
	Overtime planning of repair personnel
Cannibalization	Removing a part from another nearby system
Dynamic capacity allocation, lot sizing	Repair capacity allocation
	Lot sizing ready-to-repair parts
Joint ordering	Consolidating shipments
No intervention	Waiting for arrival of a part from the pipeline
	Fulfillment of part request from an external source (lost sales)

- Prescriptive analytics, the most advanced, focuses on the decision that should be made moving forward using heuristics, simulation and optimization with dynamic decision variables and constraints.

With the above-mentioned functionality, an SCCT enables greater visibility (Souza et al. 2020) and reliability across the value chain through coordination efforts, with better data management found by utilizing a single-point-of-truth (Chen et al. 2018). Additionally, depending on the type of SCCT implemented, there are also relevant performance improvements, such as shipping route optimization and thus lower operating cost and time-savings in a logistics CT (Souza et al. 2020) or reducing cost-to-serve in the warehouse picking function in a fulfilment CT (Alias et al. 2014). Companies can move away from responsiveness at an operational level to the strategic level (Trzuskawska-Grzesińska 2017), effectively moving from flexibility to agility (Abdelilah et al. 2018). The advancement of next-generation technology into the CT will enable complex simulation in the supply chain digital twin, which is the virtual representation of the value chain (Brintrup 2021).

Academic literature on SCCTs mostly focuses on logistics CT and inventory CT. Authors generally define their CT consistently despite discussing different types of CT, failing to provide definitions to differentiate a logistics CT from an SCCT, for example. A categorization in Table 8.2 of SCCT variants on the market was proposed by Vendor 1 (2021).

By using the above definitions to classify each SCCT discussed in academic literature, misnomers can be identified. Charłampowicz and Mańkowski (2019) classify the SCCT they discuss as a logistics CT; however, a supply assurance CT would be more appropriate. Moreover, Alias et al. (2014) also define their CT as a logistics CT despite it being a fulfilment CT, owing to the goal of optimizing warehouse picking to bundle orders and reduce cost-to-serve. Rustenburg (2016) offers details on a planning CT that simulates and shares planning between partners, shared warehouses and creates procurement consortiums. However, their paper focuses on managing the inventory of spare parts for capital intensive industries and can therefore be reclassified into an inventory CT. In some cases, two or more types of CT are put together to address the business needs of the focal company; as such, (Trzuskawska-Grzesińska 2017) proposes the term 'hybrid CT' to recognize the potential for confusion when categorizing SCCTs.

The CT operates at three levels: strategic at the top level, tactical at the middle level and operational at the bottom level (Alias et al. 2014; Charłampowicz and Mańkowski 2019; Verma et al. 2020).

Rustenburg (2016) applies the Processes, Control, Organization and Information (PCOI) model to the inventory CT they studied to make the analysis more concrete. Within the processes part of the PCOI model, a framework is used, seen in Fig. 8.2, to categorize decisions according to the functions: Assortment-management, forecasting, inventory-planning, and deployment. Within the control section, pro-active control and reactive control are the two methods of catering for any form of supply or demand volatility. The Organization part of the model explores the complexity of

Table 8.2 CT categories (Vendor 1, 2021)

CT category	Description
Logistics/transportation CT	Offers advance shipping notifications, delivery data and track-and-trace information, and visibility into inbound and outbound logistics
Fulfillment CT	Specialize in assisting package shipments, and are designed to help expedite orders while reducing the overall cost-to-serve
Inventory CT	Enable real-time insights into inventory management, with special emphasis on preventing inventory stock-outs and shortages
Supply assurance CT	Ensure there's adequate supply available, that more supply is planned for delivery, and other matters related to supply
End-to-end supply chain CT	Engineered to provide visibility across internal and external systems and processes, with applications for various departments and entities

	Assortment Management		Forecasting		Inventory Planning		Deployment
S	Assortment strategies (phase in and out)	S	Define relevant strategies	S	Define relevant strategies	S	Control framework agreements
T	Define logistic concepts for phase ins	S	Define business intelligence	S	Apply service level differentiation	T	Define checks
O	Changing parts master data	T	Define checks	S	Define business intelligence	T	Measure service levels
O	Execute assortment decisions	O	Data cleansing procedures	T	Define checks	O	Review requisitions
		O	Execute forecasting decisions	O	Execute planning decisions	O	Deploy repairs and purchase orders

S – Strategic T – Tactical O - Operational

Fig. 8.2 Strategic, tactical, and operational level model (Rustenburg 2016)

the CT and the number of parties that need to be involved and kept informed of the day-to-day running.

Notably, the monitoring and controlling function of the CT are embedded in this architecture (Alias et al. 2014; Verma et al. 2020):

- Monitoring—checks the actual against the desired values and flags deviations.
- Analysis—verifies this data is relevant and correct.
- Planning—actions are scheduled to correct the deviation.
- Execution—carries out the implementation of the actions planned.
- Knowledge—stores data collected by the previous four components for later use.

Liotine (2019) identifies multiple challenges to successfully implementing an SCCT within the pharmaceutical industry. In their paper, they outline how the data being exchanged between the supply chain partners can often be incompatible, incomplete, or unavailable, preventing the CT from being able to scan end-to-end for deviations. Though this can be overcome through quality assurance measures when dealing with different systems across the value network, complexity rises.

In regard to data visibility, (Liotine 2019) claims that integration with supply chain partners can decrease visibility owing to the difficulty in managing processes and data exchange across companies. In particular, the limitation of technology prevents the smooth flow of information between partners, most notably in goods that have high demand volatility.

The CT will challenge the culture of the organization and will therefore change the roles of individuals (Meekings and Briault 2013), potentially leading to change resistance. Additionally, the duration of implementation and company-wide buy-in will largely depend on the scale of the organization and the business areas serviced by the CT. From a study of three SCCT implementations, (Trzuskawska-Grzesińska

2017) found only one was running 24/7, with the rest only operating within business hours.

With the use of AI technology, decision-making will become increasingly automated, and in doing so, the structure of organizations will continue to change. Current operations planning roles will move towards automated data screening in its entirety so that users can focus on ever less manual interventions (Verma et al. 2020). In time this will be made redundant with the use of prescriptive analytics (Liotine 2019), allowing the role to refocus on creating value elsewhere. Additionally, through ML, the CT will increase self-learning capabilities and further reduce the need for human intervention (Verma et al. 2020).

8.2.3 Quick Action Through Effective Business Processes

Improvement of business processes promises reduction of non-value-added activities which accelerate the execution of a decided upon disruption mitigation option. Lean six sigma methods provide tools and approaches to optimize business process (Salah and Rahim 2019), however, early on already, when business process reengineering was initially mulled, its success was linked to reengineering business processes beyond minor adjustments (Hammer 1990). Since then, technology has accelerated and continues to be a focus area of investment (NASDAQ OMX 2021a, b). It should be noted that the scope of risk response is supply-chain-node by supply-chain-node (De Souza 2015), and for successful disruption management, a collaborative, coordinating approach needs to be applied both, within each single company across departments, as well as between supply chain partners (Qudrat-Ullah 2022). In addition, to maintain productivity of companies' operations, the nature of the Covid-19 disruptions was well-addressed through cloud-based systems because these could more easily support the shift to remote work (Yao and Azma 2022).

However, despite the heavy investment in technology, surveys regularly indicate that only 30% of projects are successful, while the rest either faces delays and budget overruns or doesn't achieve the intended objectives, and in some cases both (Bucy et al. 2021). One key success factor, strong senior management leadership, is the early involvement of the users to ensure the technology solution satisfies execution requirements and simultaneously delivers business objectives, on while providing (Maor et al. 2017).

This broad basis of CTs, their relevance to disruptions like Covid-19 and the drivers of effectiveness and implementation success will inform the following research interviews and analysis of the responses.

8.3 Methodology

The research was conducted with a mixed-methods approach (Saunders et al. 2019), using qualitative data from a literature review, closed access reports which were either not published or were purchased, and the authors own knowledge of the CT. This combination informed the formulation of interview questions, aiming to create a holistic overview. Moreover, in the analysis stage explored in the next sub-section, line-by-line coding was utilized. Code frequency was used to provide a quantitative form of analysis, with the most common codes being highlighted to show significance. A cross-sectional approach was used to highlight what is available on the market and academia at the time of research, rather than over a period of time (Saunders et al. 2019).

A pragmatic philosophy was used as the value in the answers was in the actionable insights that could be applied to CT in the market (Kelemen and Rumens 2011), potentially aiding companies that are looking to implement a CT to discover which is the most suitable option for them based on the market offering. Additionally, the research aimed to understand a conceptual overview of variations of CTs on the market, gaining practicable actions (Saunders et al. 2019).

An inductive approach was undertaken to generate conclusions from the specifics provided by participants in the research (Saunders et al. 2019). The data was then used to identify the themes across the responses and create a conceptual overview of what is available on the market, to compare with the theoretical overviews from literature.

The interviews with 4 interviewees took place with the intention of creating multiple case studies, with each case study representing a single company operating a CT. The questions were open-ended to allow the respondents to provide highly detailed and developmental answers in the areas they have the most knowledge in a while.

The case studies consisted of semi-structured interviews (Saunders et al. 2019), with a list of questions sent to the participants beforehand. During the interview, unstructured follow-up questions were asked for greater clarity.

The questions were the following:

1. Which of the following CT were you looking to install: end-to-end, inventory, fulfilment, logistics, supply assurance? And what was your timeline and approach for implementing regarding system, data, people, organization, business process and change management?
2. What operationally did you expect as a deliverable from the implementation of the CT?
3. How readily available was the information on the type of CT that best suit your business needs?
4. What financially did you expect as a deliverable from the installation of the CT (e.g. return on investment)?

5. What resources were dedicated to the implementation process? Was it out of the box or tailored to the business, and what was the implementation process? At what level was management buy-in?
6. What challenges arose during the implementation in the project management framework: systems, data, people, organization, business process and change management?
7. How readily available is the data across the supply chain? For example: Is there any functions in which data is not immediately retrievable? How does the CT collect, translate, upload and process data from each function?
8. How does this data aid your decision making? Where in the business process is it used? Please provide examples.
9. How does this data aid your decision execution? Where do these actions take place in the business process, and how has this changed employee roles?
10. What level of analytics is currently used in the CT? Descriptive, Diagnostic, Predictive and Prescriptive.
11. To what extent has the CT met your expectations from the scoping phases from a financial and operational perspective? Were there any unexpected benefits you did not expect?
12. How do you aim to advance this capability, and what obstacles do you envisage?

The structure for the questions covers the project lifecycle for a company looking to implement a supply chain CT, with the company scoping their requirements and what they are looking for, how the company chose the implement the CT from the vendor and the resources dedicated to this process, the everyday use of the CT such as data retrieval and informed decision making/execution, lastly the future advancements explores the unexpected benefits and how the CT met their financial and operational objectives with further exploration of what they would like to develop further.

Simultaneously, questions 2, 4, 7 and 8 have relevance for the establishment of resilience while question 9 has relevance to achieve process orchestration (enabling collaboration).

8.4 Analysis and Findings

The interview responses were coded bottom-up to identify themes for further analysis. Open coding was used to disaggregate the transcripts from the interviews into separate codes (Strauss and Corbin 1998). These codes were then reaggregated into related groups or themes. The line-by-line coding was performed in the software nVivo providing increased traceability and management of codes across multiple transcripts, alongside data visualization capabilities.

The four case studies resulted in insights within 163 individual codes. These codes were then aggregated into four themes and a total of 13 sub-themes,. This section will go through each theme sequentially, presenting the sub-themes in order

Table 8.3 Themes from the interview data

Theme	Functionality of the CT (66)	Implementation (53)	Forms of analytics (31)	Challenges (13)
Challenges	Benefits of CTs (12) Decision making and execution (4) End-to-end integration with partners (2) Running of the CT (30) User insights (18)	Project management (21) System (22) Types of CTs (10)	Automated analytics (13) Manual analytics (12) Future improvements (6)	Data (6) Implementation (7)

of importance, with quotes to highlight some of the most notable codes within each sub-theme.

The case companies will be anonymized using a Company A–D key to protect their identities while making it easy to differentiate between responses. Company A and B are both leading CT vendors on the market with experience implementing CTs into multiple clients' organizations across several sectors and industries. Company C is a 3rd Party Logistics Company in South-East Asia that utilizes a CT developed by themselves to better fulfil their contract with the client and deliver value. Similarly, Company D is a 4th Party Logistics provider, managing multiple 3rd Party Logistics Companies for their client, utilizing a CT developed internally.

The four themes found from the data were the challenges to implementing or running the CT, the forms of analytics within the CT, the functionality of the CT and implementation of a CT into a business. This can be seen in Table 8.3, with the number of individual codes stated in brackets alongside each theme or sub-theme, ordered with the decreasing code frequency from left to right.

8.4.1 The Functionality of the Control Tower

The most common theme from the data was the functionality of the CT with a total of 66 individual codes. These codes were split into five sub-themes.

With a total of 30 of the total 66 codes in the sub-theme, the day-to-day running of the CT was the most important one. In each of the four case studies, the ability to track an individual item through multiple systems was mentioned. Company D involves "shipment visibility readily available in our system, [a customer] can go through our system and track entries". Company B noted the difficulty in tracking a particular item across a company's global inventory given the required integration of ERP systems at different nodes of the supply chain, "the information you'd have to pull together can be stale, it can be out of time, and possibly outdated. So, if you

were to check your ERP systems, you might have multiple nodes, and you stitch that number together it may not be a precise number". Company C approves the notion of stale data stating the importance of "the track and trace system updating in real-time".

Moreover, three of the four case studies involved the concept of the CT sitting on top of the operations, with Company B stating that "you don't do this in a greenfield, you do this on top of an existing landscape, so they may have processes in place for data management and transformation". Company A also mentioned that end-to-end data integration takes place before a company "puts the CT on top of it".

Another key aspect of running the CT is the ability to act quickly to disruptions. Company B mentions that the use of this software 'is a reactive supply chain strategy, and [Company B] is trying to move towards proactive supply chain risk management". Company A states that this planning software allows the supply chain to be "very integrated in the short term" and the goal is to move from this approach to more advanced technology in the form of the CT to automate decision making.

Notably, in Company C and Company D, the running of the CT is highly manual, with Company D employing a team of nine people to run the CT for one client and achieving CT functionality utilizing very little smart technology and a large amount of functionality coming from Excel spreadsheets. Company C followed a similar manual approach but with fewer people and integrated systems with the customer, who they were managing, with the number of people employed scaling directly with the complexity and scope of the company they were servicing.

Company A and B, however, were far more technologically advanced with a cloud-based CT, which Company B states ingest data 24/7 rather than only when employees are at work to manually retrieve the data such as in Company C and D. Company A, however, notes that "the CT doesn't bring […] new data it's just an infrastructure to manage the actions of it".

One of the most important codes for user insights is the Alert-Based System which allows users to identify issues earlier and to act on them in a timely fashion. Company A states that business planners initially will identify the areas in the business process where there are the most disruptions, for example, stockouts, and apply alerts and controls before applying elsewhere in the organization, suggesting a modular implementation process. The alerts are then configured for particular customers or suppliers, giving priority to strategic partners over transactional relationships. This alert system is an evolution from standard manual business reporting to now automated user insights.

Company B states that by moving to automated alerts, insights are provided much quicker, which allows for real-time visibility into the supply chain that can minimize disruptions, citing the example of the "potential delay on the inbound raw material would have on the downstream customer's situations so in that case the customers' customer. And maybe shield them completely from the incident and keep my service levels [up]".

Company C notes the importance of the key performance indicator (KPI) dashboard in managing the supply chain through the CT, providing the example of shipping date versus estimated time of arrival, as well as financial metrics like operating costs.

Each of the four case studies mentioned the financial benefit of the CT, notably in reducing operating costs, moving employees' roles into more value-added activities, improving fulfilment and minimizing disruptions. Company B states that savings could be categorized into value buckets: inventory, customer service levels, time-savings, transportation costs and warehouse utilization. Additionally, the CT acts as a single point of truth, so insights are gained accurately and timely.

The decision making and execution sub-theme is linked strongly with the alerts and the actions that are taken following an alert. Notably, decision automation was mentioned by Company A and B, with procurement orders automatically expedited when a certain alert was triggered based on predefined decision maps. For decision-making, Company B provides the example of integration with external feeds such as weather allows disruptions to be identified, the CT offers a number of solutions to the user with the financial impact measured at multiple orders for each solution. The user can then decide to make a one-off stock replenishment order between distribution centers to meet customer orders.

Company B notes that the scope of their CT "understands procurement and inbound logistics, inventory and capacity and outbound. But also extends then collaboratively to suppliers and downstream to customers". This integration is also mentioned previously with understanding the customer's situation in case an order cannot be met; however, the notion of understanding the customers' customer was not mentioned in great depth by any of the case studies.

8.4.2 Implementation

In regard to the system implementation, three of the four case studies noted that the CT is tailored to the requirements of the customer. In particular, Company A notes that the CT is tailored to the most immediate problem in the organization "I always have these problems now let me solve these problems".

To get the CT operational, both Company A and B state that the client must have the multiple systems in the business integrated before the CT is implemented. Company A notes that external data integration takes place alongside the CT implementation and not necessarily beforehand. A 30-day free demo of the CT for Company B is offered on the website to allow customers to understand the system and operability before making the investment.

Both Company A and B mention how "the appetite comes while eating", figuratively describing how many clients' add-on parts to the original project as they go along—often asking for "more and more advanced analytics" as claimed by Company B. The system does not replace any existing systems, so the implementation project is usually straight forward with few challenges (Company A).

According to Company A, the implementation only required tactical level buy-in, and the C-suite does not need to be involved. However, Company B claims that depending on the size of the company, the buy-in can go all the way up to the C-suite, including in some companies, "the Chief Supply Chain Officer".

The timeline for the project can be categorized into six months to over a year for Company A and D; and up to 3 months for Company B and C. However, Company B adds the caveat that the implementation process is completed in agile methodology with a varying number of sprints will be needed.

All four case studies have stated they have developed their own logistics CT, with Company B claiming this is one of the most commonly requested CTs from their clients. Company B state that a "planning CT" is the other most common type of CT and has a "forward-looking element to it". Company C and D are both users of a logistics CT, while Company A state usually the main goal of the CT is supply assurance.

8.4.3 Forms of Analytics

Both Company A and B claim to operate with a limited amount of automated prescriptive analytics. Both companies offer CTs that predict disruptions through the various internal and external systems and offer alternatives to prevent any large-scale impact on the supply chain. This prescriptive analytic is in its infancy with limited ML and cognitive capability. Company A states that the repeated selection of one of the alternatives suggested would be automatically applied, suggesting self-learning capability. Company A mentions the digital playbook utilized means the CT pulls out the exceptions that trigger predefined limits set by the client.

Company C and D have highly manual analytics within their CT, with the only form of automation being an internal dashboard for Company C to present data. Diagnostic analytics is achieved through manually generating reports and calculating KPI's in excel, which would otherwise be automatically updated.

Company B stated that with their next update, they would aim for their CT to "start predicting the deviations and not wait for them to occur". They aim to do this by implementing ML to predict "future service levels or future inventory levels or future order coverage". Company A is looking to add demand-sensing technology to their CT using procurement and point-of-sale data to predict future demand and alter any production plans. Both companies aim to utilize cognitive technology in the future to create increasingly advanced ML.

8.4.4 Challenges

Notably, for both Company C and D, that have highly manual CTs, the largest challenge is the customer not investing in the CT functionality. In Company D the

customer did not want to invest in developing a dashboard as they saw this as unnecessary. Both companies also found it challenging hiring employees for each client and training them to run the CT to a high standard. Similarly, Company D also had the challenge of training the customer on how to use the different systems that comprise the CT.

Company B states that the largest challenge regarding data is poor data maintenance with lots of gaps in the data, especially when the people responsible for the maintenance "don't seem to take it as seriously as they might show, they might not even know that it's going to be used in an application". However, they go on to say that once this is overcome, data quality is usually not an issue as the CT can take data directly from the source. Company B explicitly stresses data readiness is the largest challenge, as all data integration issues should be fixed before they implement the CT. Additionally, as Company C points out when dealing with predicting disruptions, the CT cannot foresee certain events with the Covid-19 pandemic used as an example.

8.5 Discussion

This section will use the insights gained from the findings section to compare against the literature review. By comparing and contrasting, the two sections will be used to identify similarities, differences and developments in the literature.

8.5.1 The Functionality of the Control Tower

The findings support Yan et al. (2012) in regard to linking items through multiple systems, with Company D using the example of their logistics CT having shipment visibility across the systems. However, the concept mentioned by Hui et al. (2014) of the CT acting as an information hub in the supply network was not explicitly mentioned in the case studies. It can be inferred that for a company's internal supply chain, the CT would be an information hub, but the linking between partners CTs across a supply chain is not yet in practice.

Hofman (2014) uses TMS as an example of where users found problems arising as a result of static data, which influenced the need for a real-time CT. Company B develops this statement by carrying across the challenge into the CT, noting that the same issues with outdated or out of sync data. The challenge mentioned by Hofman (2014) is not unique to the TMS, and so by linking multiple information systems, the challenge can arise in each system, representing an increasingly difficult challenge according to the number of systems being integrated.

One area missing from the literature is the existing IT set up within a company before they implement a CT. Both Company A and B note that the end-to-end data integration takes place before the vendor places the CT on top of the systems. The

literature on CTs indicates the data integration of all systems is part of the implementation process; however, from the two case studies mentioned, this is not the case.

The leading brand of supply chain planning software that was mentioned by Company A and B was not mentioned at any point in the literature review, as the journal articles analyzed did not involve any specific use of software on the market and instead offered insights on the CT topic as a whole. However, the strategy employed by this software supports Williams et al. (2013) and their model in Table 8.2, claiming that supply chain responsiveness can be achieved through end-to-end visibility of demand, supply and market conditions. Therefore, this research offers the insight that the CT is an evolution from this supply chain planning software as companies move from reactive supply chains to proactive supply chains.

Additionally, the literature review mostly focused on CTs as an information system; however, through the research Company C and D demonstrated that the CT concept could be achieved manually with employees running the system rather than through an information system. For a CT to be run by human resources rather than an information system, it can only be in operation during business hours; this is the case for Company C and D, while Company A and B can offer a CT that ingests data 24/7. That said, the paper by Trzuskawska-Grzesińska (2017) notes that only one of the three CTs studied was operational 24/7. However, the two that functioned only during business hours still had a dedicated IT solution and so cannot be classed as a manual CT.

One of the key findings from the data was the importance of the alert-based system, which is not emphasized to the same extent in literature. The literature analysis focused more so on the exceptions-management, which pulls is the algorithm written by the system users to set deviation tolerance parameters. The findings instead focus on the alert and notification rather than the algorithmic precursor. However, Company A stated that the alerts were prioritized for strategic partners over transactional relationships, which is consistent with Alias et al. (2015) that the insight from the alert is prioritized by urgency and impact, so the user is not overwhelmed with unsorted data.

The outcomes of decisions made through the system are not necessarily communicated to all relevant parties as mentioned by Chen et al. (2018), with the case studies analyzed appearing to be an information hub for the users of the CT with any communication of actions taken or justification for decisions being provided outside of the system. Moreover, the emphasis on digestible insights in literature is not consistent with the findings, which Hofman (2014) claims is tailored to the job function the user is in, so the most relevant insights are provided and avoid overwhelming information. Given this was not mentioned by any of the case studies, it can be assumed that the insights provided are a 'one-size-fits-all' and are not yet tailored to the job function.

The findings from the data mainly revolved around the financial benefits of the CT, whereas the literature had an equal balance of financial benefits and operational benefits. From the value buckets presented by Company B, the warehouse utilization value bucket was consistent with the reduction in the cost-to-serve in the warehouse function of a fulfilment CT stated by Alias et al. (2014). Additionally, the value

bucket from time savings, transportation costs and customer service levels were supported by Souza et al. (2020). However, the inventory value bucket was not explicitly mentioned by the mentioned authors, although it can be inferred from better warehouse utilization and planning optimization across the supply chain.

Outside of the financial benefits, there were a few operational benefits to the CT that both the findings and literature agreed on. Firstly, the case studies mentioned the CT minimizes disruptions whilst improving fulfilment; this agrees with Souza et al. (2020) that greater reliability across the value chain results from the CT. Moreover, Liotine (2019) supports Company A's belief that the CT moves employees' roles into more value-added work with automation of repetitive activities. This move also supports the notion of reliability, where basic non-value-added areas susceptible to human error are undertaken by a computer, vastly reducing the likelihood of error. Chen et al. (2018) note by utilizing a single point of truth, the CT can facilitate better data management; the case studies support this with the mention of insights becoming more accurate and timelier.

There were, however, some benefits not found in the case studies that were mentioned in the literature review. Notably, the advancement of technology supporting the supply chain digital twin suggested by Brintrup (2021), creating a virtual representation of the value chain. This technology ties in perfectly with the CT, as predictive analytics can be used to provide alerts for machine maintenance that can proactively prevent machine downtime, for example. Additionally, the findings did not mention the move from responsiveness at an operational level to the strategic level brought forward by Trzuskawska-Grzesińska (2017).

The literature and findings agree on how the CT reacts to the alert system being triggered. As mentioned by Alias et al. (2015), Topan et al. (2020), Trzuskawska-Grzesińska (2017), recommendations are provided to the user to overcome the deviations in the data. All four case studies involved some form of this recommendation, with Company C and D manually making the recommendations and executing plans; and Company A and B utilizing a digital playbook. The digital playbook would involve diagnostic analysis of the urgency and potential impact of the deviation on the supply chain, using both internal and external data feeds, and provide the predefined corrections. There would be multiple recommendations to correct a deviation with Company B stating that multiple-order analysis is conducted to fully understand the knock-on effect of a correction on the entire supply chain.

From a decision execution point of view, the case studies support the intervention examples provided by Topan et al. (2020) in Table 8.1. Notably, Company B provides the example of making a one-off replenishment order between disruption centers, which is categorized as an 'Expediting Intervention' by Topan et al. (2020). This is split into lateral transshipment reactive and proactive. Despite this differentiation not being supported by the case studies, it follows the expected development of intelligence within the CT so that the alert can be programmed earlier in the value chain with more data points to become proactive rather than reactive.

The integration with partners found in the case studies is consistent with that of the literature. Interestingly, Company B describes how their CT takes into account

upstream and downstream of the supply chain, so the user can make informed decisions factoring in multiple partners as per Chen et al. (2018). However, there was no mention in the case studies of integration with partners' own CT. Evidently, there can be integration between a company's systems and some partner systems, notably mentioned by Company D, but currently, there is not the capability to link entire CTs together.

When describing CTs as end-to-end, it can be assumed that this refers to a company's 'Tier 1' supplier and customer being integrated in some capacity. Company B notes how an understanding of a customers' situation can prevent a serious knock-on effect from a disruption onto the 'Tier 2' customer. However, it was not made clear whether this intelligence was within the CT itself or was from the users' understanding of the nature of the supply chain relationships when looking at expected impacts of correcting deviations. Given that the integration with partners' is limited to a handful of systems currently, it can be assumed that the latter is the case. As CTs evolve, partners' CTs will be knitted together to provide an all-encompassing view of the supply chain, potentially stretching into the second tiers of the supply chain.

8.5.2 Implementation

The literature and case studies approach the CT system from different directions. The literature appears to provide system architecture for in-house development of the system rather than from a vendor. Company C and D, who deploy basic CT functionality, have both developed their CT in-house with an invoicing manager being designated similarly to the business transaction manager, and value chain designer and coordinator roles being established. The rule handler and sensor evaluator can be said to be the dashboard each company uses to monitor the KPI's to detect deviations.

However, the more advanced CTs by Company A and B are developed in-house to be implemented in a clients' organization. Therefore, from the perspective of a company implementing a CT, they are buying in the solution. This is an area missing in literature as academics have so far been limited in studying vendors. Company A states that the CT is implemented where the most immediate problems are in the value chain; this provides an insight into how the system is more modular than a 'plug-and-play system that covers an entire organization. Both Company A and B tailor their CT to the business problem with the client, connecting relevant data feeds and programming appropriate algorithms for the exceptions management system. It can be said these two vendors do not offer an out-of-the-box solution or a fully bespoke system but offer something in the middle—an established system tailored to the requirements of the client.

The case studies support the MAPE-K[2] control loop suggested by both Alias et al. (2014), Verma, Koul and Singh (2020). All four case studies monitor and analyze

[2] Monitor-Analyze-Plan-Execute over a shared Knowledge.

the data automatically, whilst Company A and B have more advanced planning, execution and a limited amount of the knowledge function—notably, with Company A stating that repeated options executed from a deviation are self-learned to become fully automated.

The project management aspect of the CT is largely missed by academics; instead, they mostly focus on the functionality of the CT. The findings for the project management sub-theme can be split into three: the buy-in, the scoping and the timeline. The buy-in from management can be plotted against the three levels the CT operates at—strategic, tactical and operational. Verma et al. (2020) describe these layers as designing, planning and execution levels, respectively. Company A states that the implementation project takes place at the tactical level without the need for the C-suite to become involved. This could be because it can take place within a part of the value chain, such as logistics, where only the logistics management needs to be involved in setting up the system as they will be responsible for it. The C-suite would likely need to sign off on the project as it would be a large capital expense paying for the CT and the implementation consultants; however, they would not need to necessarily be involved in the full project. That said, Company B states that depending on the size of the organization, the complexity of the implementation and numerous other variables, then buy-in could be tactical as well as strategic level with the Chief Supply Chain Officer, Chief Executive Officer or Chief Financial Officer being involved throughout the project.

For both the scoping and the timeline, the literature does not involve any information to discuss. This could be owing to the focus on in-house development of the CT rather than from purchasing from a vendor and thus having to create an entire CT from scratch leading to an ill-defined timeline. Interestingly, when purchasing from a vendor, the implementation of the CT is relatively straightforward as it is adding to the existing landscape and does not replace any existing systems. Moreover, from the experience of Company A and B, the clients demand more and more capabilities as the project goes on, most frequently asking for more advanced analytics, leading to what Company B describes as 'scope creep'. The timeline for the implementation is broken into 'sprints' by Company B, which each last three months, the number of sprints required for the project is decided by a number of factors, for example, scope, the number of partners integrated, the number of systems integrated and size of the company. Company A and D stated their implementation period was from six months to a year, most likely owing to the same factors previously mentioned. For both Company A and B, full data integration of all systems takes place before implementation, which could explain the relatively short 'sprints' provided by Company B. However, from a clients' perspective, the implementation period would take this project length in addition to the time it takes to fully integrate all relevant systems across the organization, also scaling with complexity and the factors mentioned.

The findings largely support the literature on the types of CTs employed. The definitions by Vendor 1 (2021) were used in the literature review to provide accurate classification of all CTs discussed by academic literature, in some cases, re-classifying wrongly labelled CTs. All four case studies have in some capacity developed a logistics CT with Company C and D creating a bespoke logistics CT for their own use.

Company B states that the logistics CT is one of the two most common types of CT developed, with a 'planning CT' being the other.

Company B provides only a small amount of detail on the planning CT, describing it as having 'a forward-looking element to it'. The only academic journal to mention a planning CT was Rustenburg (2016), using it to label a CT aiming to manage the supply and demand for spare parts in an organization; however, in the literature review, this was categorized as an inventory CT given that it is trying to prevent stockout and shortages of the inventory for spare parts. Rustenburg (2016) defines the planning CT as a system that aggregates the procurement, warehouse utilization and inventory plans across multiple companies. This is supported by the current CT capabilities as only a small number of systems would need to be integrated across partners to achieve this. This planning CT concept can be used to back up the definition of a 'hybrid CT' coined by Trzuskawska-Grzesińska (2017), as the warehouse utilization would be a fulfilment CT capability, aggregated procurement could be a supply assurance CT if there is focus on high service levels and inventory plans can be classified as inventory CTs. A planning CT can have the capabilities of all three merged into a single CT, rather than having three separate CTs operating in the organization. Therefore, Company B supports Trzuskawska-Grzesińska (2017) hybrid CT concept and develops further the definitions provided by Vendor 1 (2021).

8.5.3 Forms of Analytics

Company A and B support the four layers of analytics provided by Delen and Zolbanin (2018). Both systems have the ability to link internal and external data feeds to provide intelligence to the user previously not possible through standard business systems. However, despite having capabilities at all four layers, the predictive and prescriptive analytical layers are more basic than the first two layers, employing a small amount of AI and a very limited amount of ML—supporting Verma et al. (2020) that this technology is at its infancy stage of a product lifecycle.

Liotine (2019) notes that AI is able to factor in weather, expected delivery times and competitor information in the analytics engine. From the data, it can be said the first two are currently possible; however, competitor information is not yet viable. Company B makes the important distinction between Planned Time of Arrival and Predicted Time of Arrival, with the latter being the more accurate analytic, factoring in delays and disruptions. This can be said to be an intermediate amount of predictive analytic, as the CT can analyze disruptions to shipments, allowing the system to trigger recommendations for rerouting shipments to avoid disruptive weather systems.

Moreover, through the use of the digital playbook, prescriptive analytics can be utilized, and actions recommended, with Company A and B both having diagnostic analysis on each recommendation to provide the simulated financial impact of each recommendation. Company A also highlights the ML capability of their CT, with

the repeated choice of a recommendation for a certain disruption becoming fully automated as the system learns which options the user prefers to exercise.

Company C and D employ a great deal of manual analytics, with descriptive analytics being available in excel spreadsheets or an internal dashboard. Diagnostic analytics are available to the user; however, this can only be achieved through manually requesting a report from the system. Through the use of excel, both companies can also use basic data visualization to explore the data further, and so both Company C and D can be said to be at the descriptive and diagnostic level of analytic capability provided by Delen and Zolbanin (2018). Predictive and Prescriptive analytics are not yet available in their CTs owing to a lack of investment.

The current analytics, both automated and manual, largely focus on the internal supply chain with some integration of external feeds. The future CT for Company A and B will involve more and more advanced analytics for internal to the supply chain whilst tapping into the vast potential of external data. Company B is focusing on more advanced predictive analytical capabilities alongside increasing the volume of predictions made. Company A is aiming to add demand-sensing technology using point-of-sale and procurement data to predict demand, which Liotine (2019) claims is a current capability of a CT. Given that both Company A and B are advanced CT vendors, it can be said that Liotine (2019) is correct in the application of AI in transport information but not in demand-sensing. Additionally, the prescriptive analytics talked about in the literature review is evidently idealistic considering what is currently available in CTs, with simulation and heuristics being used in a limited capacity. However, integration with a supply chain digital twin suggested by Brintrup (2021) was not mentioned by the case studies but will be an important capability added-on by vendors to increase the predictive capabilities—identifying when machine maintenance is required and therefore reducing machine downtime.

8.5.4 Challenges

The literature around CTs is mainly focusing on the challenges associated with data, with very little on the implementation side of the CT. Company D notes that there is a challenge with training up the client to use different systems when implementing the CT—Meekings and Briault (2013) suggests there is often a challenge with inertia meaning users are reluctant to learn to use the new system. However, Company A states that users want visibility into their supply chain so are often more than happy to learn to use this system. Beyond this, there is the challenge faced by Company D is the client not wanting to invest in more advanced technology, as they were happy with the current service based on how much the contract was worth. This is preventing new improvements from being made to the CT capabilities and provides a useful insight into the implementation of more basic CT projects.

The problems with data maintenance and quality mentioned by Company B follows the challenges identified by Liotine (2019); specifically, that data being exchanged between companies can be incomplete, incompatible or unavailable,

preventing the effective running of the CT. Company A and B both stated that the data integration takes place before they implement the CT, but Company B states that they still have problems with the data integration even after this process. However, this challenge in the findings is from an implementation perspective rather than the day-to-day perspective that Liotine (2019) has employed. It can be said that both perspectives are correct as there will be these challenges most notably before implementing the CT, but as systems and versions become replaced or updated, then challenges with integration will arise again.

Data visibility was not mentioned in the case studies as an issue, as once the systems are integrated, then the CT for Company A and B can view this data in full at all times. Company C also notes that despite the focus on predictive analytics, some disruptions cannot be foreseen, such as the Covid-19 pandemic. This is an important insight as literature fail to recognize the limitations of the intelligence potential.

8.6 Summary and Discussion

The types of CTs found in the literature review were mostly supported by the definitions provided by Vendor 1 (2021), Table 8.2. Indicating there were multiple types of different CTs a company can choose to implement.

The scope of the term "end-to-end" was suggested to be fully end-to-end, which in supply chain context is usually to tier-2 customers and suppliers. However, from the findings, this is not the case. As seen in Fig. 8.3, the scope of the CTs extends to tier-1 in the supply chain, represented by the grey box within the diagram. Outside of the grey box, it can be seen that the full potential of each of the CTs is unfulfilled.

The findings support Trzuskawska-Grzesińska (2017) concept of a 'hybrid CT' rather than mutually exclusive CTs suggested by Vendor 1 (2021). As such, Fig. 8.4 has been created to highlight the nature of implementing a CT from a vendor. The stock CT will have a user interface, analytics engine and exceptions management system, amongst other components. Every CT will be connected to the systems that facilitate end-to-end visibility whilst the other business process, and relevant systems will be chosen according to the scope and immediate business problem needing to be solved. The client can choose multiple business processes when integrating, allowing them to create a 'hybrid CT'.

To account for the in-house development of basic CTs and the distinction between this and the often more advanced CT by vendors, Fig. 8.5 has been created. The features of each CT are included in the diagram, with the most advanced features being found in the next generation CT not yet available on the market.

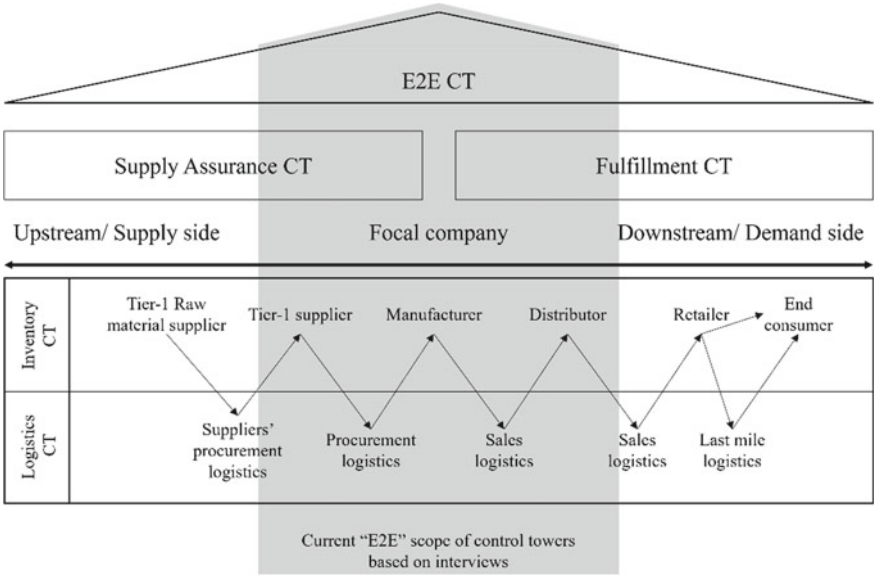

Fig. 8.3 Scope of CTs from the case studies versus literature review

8.6.1 Insights and Implications Post-Covid Practice

The benefits of CTs in managing disruptions from the impact of Covid-19 and the related public health policies hinges on the combination of increased visibility, improved business processes, and accelerated mitigation execution through automation.

As a first step, once data has been integrated from internal and external sources, then supply chain visibility has been established which are today's basic CTs. This can be leveraged for risk identification as well as disruption management. To maintain supply chain operations, risks have to be identified early enough to allow mitigating actions before they occur as a disruption. When a disruption occurred, visibility informs the options for a recovery response. However, at this point, visibility is subject to the quality of the decision making and execution.

The second step is business process improvement and orchestration, where users can decide for a specific solution option and execute it quickly. These are current advanced CTs. Depending on the completeness of the visibility, these available options can pull any or all the four levers of disruption management. The speed of the execution is affected by handover points in the business processes where data must flow between systems or steps need to be performed manually. During Covid-19, due to slow processes in the decision option generation (Cecere 2021), simplified approaches proved more beneficial.

The third step in responding to visibility is enabled by a full integration of data without manual intervention in the processes required, i.e. the next generation CTs.

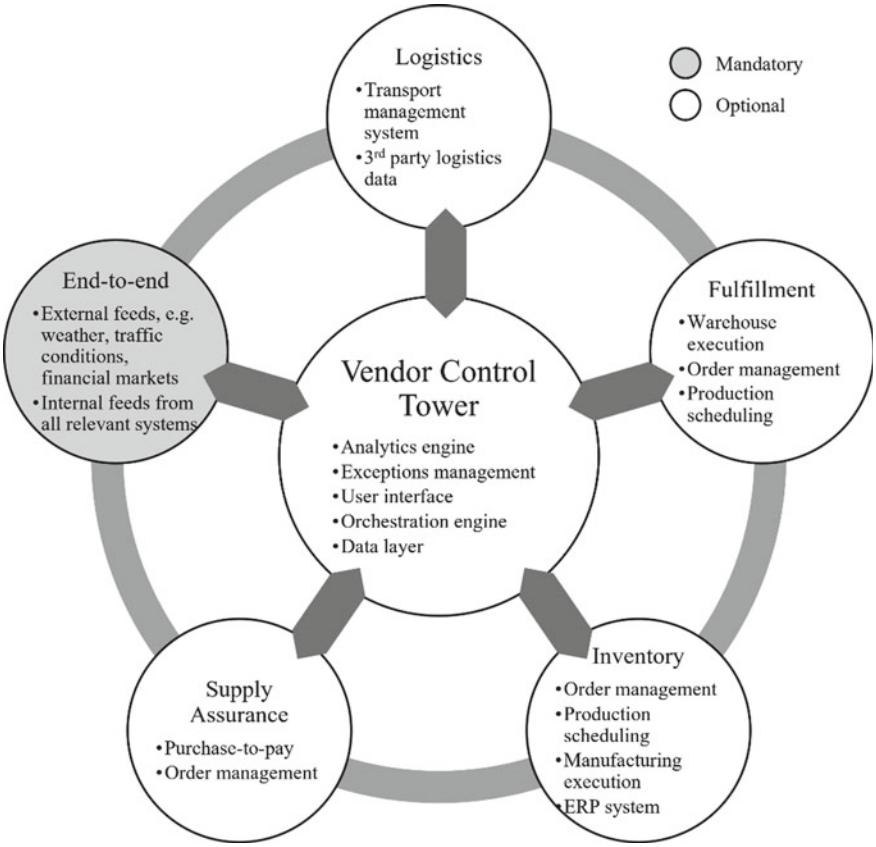

Fig. 8.4 Conceptual overview of CT architecture

Basic Control Tower	Current Advanced Control Tower	Next Generation Control Tower
Highly manual, run by a team of people, internal dashboard to monitor KPI's, descriptive and diagnostic analytics, cannot facilitate decision making and execution within the system.	Comprehensive capabilities, run by the vendor software platform with shipments and disruptions mapped on a world map, minimal human interface, limited AI and ML application, a degree of predictive and prescriptive analytics with recommendations analyzed for multiple-order financial and operational implications aiding decision making and execution within the system.	Nu human interference, fully automated decision making and execution based on previous actions and digital playbook, advanced application of AI and ML in the analytics engine, sophisticated predictive and prescriptive analytics with cognitive abilities introduced, integration with partners' control towers and a digital supply chain twin.

Fig. 8.5 Evolution of CT capability

This allows user(s) to focus on the assessment of the available decision options while the decision for a specific option triggers the automated actions described in the literature review, accelerating the mitigating action further.

Looking beyond Covid-19, CT implementations have to be assessed for their achievement along these three dimensions. Visibility alone is not enough; it has to be complemented with business process execution and its acceleration through automation.

8.6.2 Limitations and Future Research

This research has multiple limitations which should be addressed in further research. Practitioner literature on CTs mostly comes in the form of either consultancy reports or product offerings from SCCT vendors in the market which are inherently biased because the purpose of these materials is to facilitate the selling process of each company's offerings. More academic research would be helpful in grounding the discussion. The interviews are based on limited case studies, few insights from users and the context within which each is operating. For example, by geographically separating companies, various working cultures will impact the structure of the supply chain, CT with the most technologically advanced countries deploying AI while emerging markets using a higher degree of manpower and thus human intervention. It will therefore be important to recognize the geographical and cultural impact on the SCCT before making generalized insights. Also, while discussing the SCCT and business processes, the aspects of organizational setup, including whether work is performed by staff remotely or in co-location, may have implications on the business process design and its execution. In turn, this should be complemented by research into the supply chain decision making framework and models, as well as whether there are dependencies between business process design and the organizational design responsibilities and accountabilities in relation to the model developed in this chapter.

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Chapter 9
Phenomenological Study of Pharmaceutical Supply Chain in Pakistan: Innovative Approaches to Minimize Operational Inefficiencies

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Abstract One of the major parts of the healthcare industry is the pharmaceutical sector. When we focus on the pharmaceutical supply chain, the process of delivering medicine is long in duration and has been characterized as more complicated in structure than other organizations. The objective of this study was to find issues associated with the supply chain of pharmaceutical firms in Pakistan, in addition; to what approaches can be used to minimize and eliminate the inefficiencies in the operations of the supply chain in pharmaceutical firms. The research followed a phenomenological method approach using explorative design. The research employed qualitative method using in-depth interviews. The study found that there are some major issues that act as significant operational inefficiencies in the context of Pakistan. Government regulations, product expertise, continuous forecasting, and technological advancement are major issues.

Keywords Pharmaceutical supply chain · Inefficiency · Healthcare industry · Innovative approaches · Phenomenological study · Pakistan · Government regulations · Technological advancement

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9.1 Introduction

Healthcare organizations should focus on everyone's health in their region by advancing in reachability service, and dependableness so every individual who requires medical care from the healthcare organization should receive a great experience (Chassin 2013). Human development and progress is a continuous process and every industry should excel in it including developing healthcare organizations, for that it requires continuous laying out capital for uninterrupted advancement to sustain its effectiveness in terms of operations and services (Khan et al. 2021a). In the US, many hospitals in rural areas have been closed due to financial reason (Kissi et al. 2021). At the same time, prices in healthcare are moving up at a high speed (Bhandari et al. 2020; Pondhe et al. 2006). To cut down prices, healthcare organizations have to achieve maximum efficiency in their operations and services (Mubarik et al. 2021). On the other hand, healthcare organization efforts are inconvenient when we note the differences with other sectors (Miao et al. 2022). The health sector is distinctly separate from other sectors because the malfunction of health services will affect society (Ferreira et al. 2018).

One of the major parts of the healthcare industry is the pharmaceutical sector. In spite of the fact that the pharmaceutical industry has made it possible for drug makers to bring forth new and more effective medicines, continuous research should be conducted (Miao et al. 2022). In the field of supply chain effectiveness to make the process better than before (Khan et al. 2021a). Widespread research should be conducted on matters that affect the supply chain of pharmaceuticals (Narayanamurthy et al. 2018). When we focus on the pharmaceutical supply chain, the process of delivering medicine is long in duration and has been qualified more complicated in structure than in other organizations (Birkie et al. 2017). The aim of this study is to provide more insight and practical information on the operational inefficiencies of the pharmaceutical supply chain used in Pakistan.

This chapter will contribute to the lack of attention to the whole network of the existing Pharmaceutical Supply Chain. Whole pharmaceutical supply chain systems need to be improved in terms of quality, visibility, speed, and cost to function effectively. First, this article will examine and investigate the pharmaceutical supply chain practices to identify factors that influence system inefficiencies, which is an important step in developing and improving the end product offering for the customer (patient). Secondly, it is necessary to understand strategies implemented in the pharmaceutical supply chain to identify innovative approaches that could be implemented to enhance the performance of pharmaceutical supply chain.

From the above discussion, objectives of this chapter are as follows:

1. Find the root cause of problems related to poor pharmaceutical supply chain performance.
2. Optimizing the practices implemented in the pharmaceutical supply chain.
3. Identify innovative approaches that can improve operational efficiencies in the pharmaceutical supply chain.

From the above objectives, we derive the following research questions.

An exploratory and qualitative approach was chosen and followed; these questions are formulated for the direction of our book chapter study methodology:

1. RQ1. What are the challenges associated with the whole process within the pharmaceutical supply chain in Pakistan?
2. RQ2. What innovative approaches can be implemented in pharmaceutical supply chain to make system more effective?

9.2 Theoretical Background

Research scholars have formulated detailed, clear and deep perceptions into the area of operational efficiency, providing useful and valuable definitions. It is accepted that operational efficiency is majorly affiliated to "Doing things with right steps" (Forsund 2017). Efficiencies in operations can be estimate by the final result of the procedure in direction of the five performance factors such as caliber, being flexible, fast (logistics), being dependent and charging cost (Birkie et al., 2017). Measurement of efficient process relies on the context of environment (Bamford et al. 2015; Khan et al. 2022b). Centering towards the process of producing services of healthcare, there is requirement to make healthcare efficiency better regarding service of quality, satisfaction and safety of patients and in costing (Guerrini et al. 2018; Khan et al. 2022c).

The greater force applied towards organizations of healthcare to reduce their spending on pharmaceutical converts and this is required immediately (Al-Balushi et al. 2014). Expecting to get the better of the restrictions of an organization that is function based (Mubarik et al. 2022). Adopting approaches that leads towards improvement are an essential part of healthcare organizations (Bam et al. 2017). Even so, mostly such approaches are uneven and methodologically restricted (Narayanamurthy et al. 2018). Some important problems are highlighted regarding low performance by the extant literature detailed review.

Even though the pharmaceutical supply chain objective is to secure demands of customers in effective manner, that means patients are able to receive medical products easily (Mubarik et al. 2022). It is portrayed as enterprise with complexities as it has to meet with aims with different conflicts and constraints that are not traceable (Bam et al. 2017; Arif et al. 2023). Multiple researchers have gone through the pharmaceutical supply chain, says that multiple elements are involved in inefficiency to the process (Bhakoo et al. 2012).

When different stakeholders are involved in pharmaceutical supply chain process, for example like physicians, management, suppliers, staff working in clinics, and pharmacists, than inefficiency increases in logistics of drugs (De Vries and Huijsman 2011, Zaman et al. 2023b). Everyone in the pharmaceutical supply chain are designated to different roles and have their own responsibilities and are responsible for their actions, so if the information is not shared accordingly it results in lower strength of flow of information between the departments (Bhakoo et al. 2012; Zaman et al. 2023a). Adding that physicians are the decision makers and if purchasing of

prescribed drugs are without brought into focus about extended knowledge of supply chain management SCM and operation management OM patterns then it will result into lower performance (Bhakoo et al. 2012). Breen and Xie (2015) focused towards the pharmacist's role that how well they explore their skills of critical management that is required to effectively perform. Davies and Edwards (2013) emphasized that the growth in constant manner of pharmacy sectors need to have more qualified pharmacist, if we not focus on the modules of management that lacks it result in under growth. Supply chain management skills are needed when pharmacist enhance their quality regarding service (Uthayakumar and Priyan 2013).

Pressures from regulatory and institutions causes issues in identifying exact forecast of sales with side to formulation of long cycles of the medical products of pharmaceutical causes difficulty if applying strategies of supply chain SCS (Bhakoo et al. 2012; Khan et al. 2021b). There is hard in foretelling the accurate demand for drugs, partially because of the standard nomenclature lack and partially because of the factual information that drugs are stored in multiple units of healthcare organization (Mustaffa and Potter 2009). Likewise, it is thought provoking to foretell the patient mix, apprehend their requirements and the supply intake (Scheller and Smeltzer 2006), and in sudden unforeseen interventions. This unexpected demand shows that it is the element that forces healthcare sectors to store high degree of safety stocks prevent the occurrence of uncertainties just like demand fluctuations in daily basis and bottleneck supply (Bhakoo et al. 2012). These patterns could rise the stage of wastage discovered in pharmaceutical supply chain, that means many expired or unnecessary drugs should have been disposed of, and that hits the potential level of environment and living health (Wang et al. 2015). Drugs are not cheap products and also can change over to harmful or unusable products for customers as they get closer to their expiry (Cherrett et al. 2012; Jiang et al. 2018).

An important issue, hence, dealing this industry is inefficiency in the process that is related to distribution of pharmaceutical (Miao et al. 2022). Robust logistics and systems with proper planning can eliminate inefficiencies in the existing system (Jamali et al. 2010; Khan et al. 2022a). It is known that standard distribution strategy systems can play vital role in instructing policies in other logistic sectors are not easily applied in pharmaceutical supply chain (Papalexi et al. 2015) because of the listed numbers in points of consumption, such factors like lengthy lead time, and extreme unexpected nature of when we talk about bio pharmaceutical manufacturing, which have made uncertainties (Bhakoo et al. 2012; Zaman et al. 2023b).

Figure 9.1 shows the structure of this complex supply chain, including the upstream, central, and downstream domains of the pharmaceutical supply chain that involve various stakeholder groups.

The pharmaceutical supply chain does not have single dimension and it involves various lines in distribution. For example, when we talk about the upstream area of pharmaceutical supply chain it only involves the pharmaceutical companies that manufacture the goods and this area can have middleman/distributor. The writer believes that the diagram plays an important aim in illustrating the complex pattern of real situation. Literature shows that lack of focus in involved in pharmaceutical supply chain in study (Narayana et al. 2014). Usually, scholars focuses on the

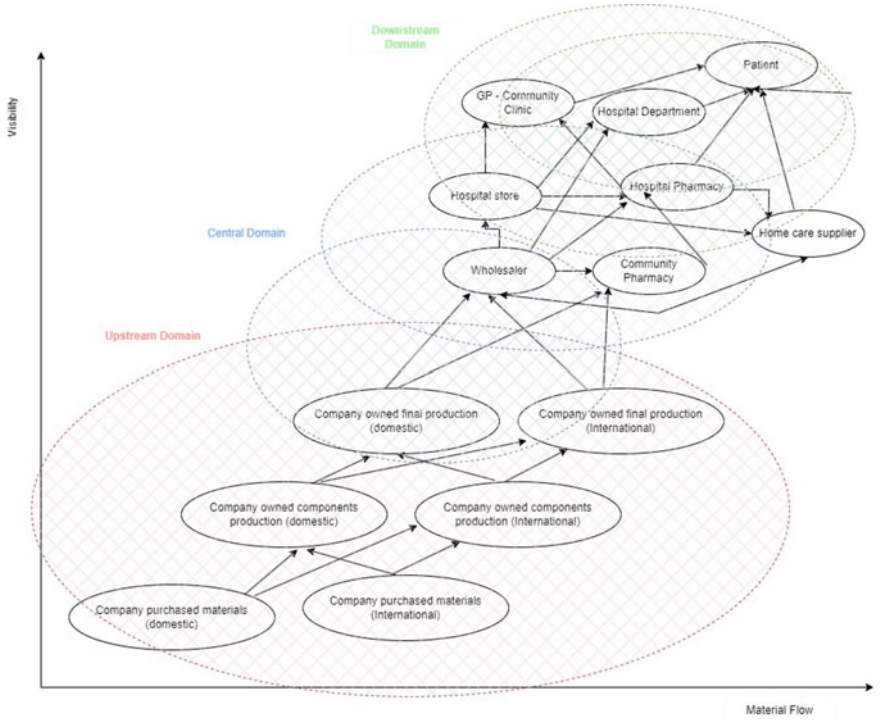

Fig. 9.1 Structure of the supply chain. *Source* Papalexi (2017)

processes of upstream business, that brings out rising interest in interactions between the Research & Development and pharmaceutical manufacturing in biotechnology sector (Sen et al. 2013). This study will contribute to the existing lack of focus on the pharmaceutical supply chain system as it investigates the pharmaceutical supply chain practices taking place in the Pakistan.

The above factors impact drug logistics and hinder improvement efforts. However, there is a wealth of research examining inefficiencies in pharmaceutical logistics (Bhakoo et al. 2012; Xie and Breen 2014). The focus of this study is to extend the existing literature by examining the pharmaceutical supply chain system in Pakistan. This will identify factors that affect the system by decreasing performance (in supply chain) applied in pharmaceutical companies of Pakistan. This study raises awareness of such factors that pharmaceutical companies in Pakistan can choose to avoid or take advantage.

9.3 Methodology

9.3.1 Context

Phenomenology approach was used, as we wanted to know the shared expressions of experienced managers in pharmaceutical companies (Khan et al. 2022c). Researcher conduct data from interviewee's by their enliven experience in pharmaceutical firms in Pakistan. The research was exploratory, as the issue has no clear answers in the context of Pakistan. Researcher conducted in-depth interviews with candidates in related fields**.** Researchers select samples that meet several criteria and answer the research questions to reach for aim and objectives of study (Matthews and Ross 2010; Ishizaka et al. 2023).

9.3.2 Development of Semi-structured Interviews

Semi-structured interviews are meetings in which the interviewer asks open-ended questions rather than following a rigid, formalized list of questions. The interview included a list of her three-part open-ended questions:

(1) The first part relates to general questions about research phenomena and the role of respondents within them.
(2) The second part contained questions specific to issues identified through review of the report and previous research, such as factors that impede effective supply chain processes.
(3) Part 3 focused on respondents' personal views and beliefs about whether perceived issues related to system inefficiencies could be improved by implementing improvement approaches.

9.3.3 Qualitative Data Collection

Interviews were conducted from three managers of different pharmaceutical firms. Interviews were used to gather thick description by conducting detailed interviews.

9.3.4 Data Analysis

Conducting thematic analysis, it is a basic method of qualitative data analysis. This tool allows researchers to identify and analyze themes within the collected data. Our model contains process of five methods to analyze our data gathered through interview. Researcher started to select the significant statements that are related to the

study as shown in Table 9.1. Then in Table 9.2, all those significant statements that were extracted from transcription are now converted into formulated meaning that shows the expressions and what interviewees meant. Then in Table 9.3, we formed initial themes by merging similar formulated meaning so we can contextualize our study. In last Table 9.4 shows the formulation of cluster themes by merging of initial themes and then transforming them into emergent themes.

In particular, after the recording has been transcribed and formed into transcription then following steps were followed as shown in Fig. 9.2.

9.4 Higher End Qualitative Analysis

Table 9.1 shows the higher end qualitative analysis where significant statement are separated from the overall transcription.

Table 9.2 shows how meaning is given to the extracted significant statements keeping in mind the context of the situation, setting and the research in mind.

Table 9.3 shows how initial themes are derived from the formulated meaning statements that were extracted from the significant statements.

Table 9.4 shows how Themes clusters are extracted from initial themes that were derived from the formulated meaning statements which were extracted from the significant statements.

9.4.1 Findings

In Table 9.4, four key emergent themes are taken from the information shared by the managers of pharmaceutical firm in Pakistan. These emergent themes give the main points behind the operational inefficiencies of pharmaceutical supply chain in Pakistan and a how can we overcome by choosing such innovative approaches that can eliminate such inefficiencies. These factors have been classified into four themes, emerge from the data and be interpreted and explained in more detail in the following sections.

1. Government Regulations
2. Product Expertise
3. Continuous Forecasting
4. Technological Advancement

9.4.2 Government Regulations

Researcher finds out that government regulations are important while conducting business but it negatively affects the business process. Government policies badly

Table 9.1 Qualitative inquiry process

Significant statements	Address
So the major issue, what we so far faced like in few countries where our major contribution in sales, which are coming from are selling in PKR in our local currency but our import, the raw materials are in dollars	Transcription 1, P 53
So when we score that revenue in PKR and selling in PKR. And then when we convert in the open market to the dollar, so that basically hurt our profitability and definitely the supply chain	Transcription 1, P 53
Like in the current economic situation as I mentioned before that the LC was stop by the Ministry of Finance Pakistan, that they have imposed sanctions that no one can issue the major and the big volume LC because of the inflation and all that	Transcription 1, P 53
So this is the factor which majorly influencing the import of raw material because if we are unable to import the raw material so how can we convert it to finish good and how can we supply to the field of sales and how can we secure our business revenue as well as profitability of the principal	Transcription 1, P 53
Actually, you know, I myself as a business student, there are factors which majorly influencing the business like some of which are in the grip of the internal principle	Transcription 1, P 53
So all these factors effect and what I mentioned before the major challenge is the economy of the country to that is one thing	Transcription 1, P 53
Therefore, the next thing is that I mentioned before that our major sales are coming from Sri Lanka and Afghanistan	Transcription 1, P 53
In Sri Lanka you can see the same problems. They are facing the economical crisis and in Afghanistan in last August, the regime change leads to the major breakthrough and economical crisis as well as the LC's opening	Transcription 1, P 53
What condition Pakistan today is passing that it is passed by Afghanistan even still the financial institution are closed, so that what it hurts that not only the pressure on the import business to import those raw material but as well as selling those materials underground in the field of sales	Transcription 1, P 53
So definitely we are unable to even get dollars through the legal channels	Transcription 1, P 53
So ultimately this is one thing, the second thing which I have observed as a business student (supply chain), that even Pakistan is now imposed a new duties and shipments or those process in PKR like in Afghanistan if I have got order of 56 million PKR, so now I'm unable to grab that money through the legal channels	Transcription 1, P 53
So what I need to I should have that money to supply that drug like that product that finish good because I have a team there that needs to supply that	Transcription 1, P 53
Pakistan government is not cooperating and even now they impose a new tax of 1.5% against the invoice generated	Transcription 1, P 54
If you receive the payment in the banks against the export in Afghanistan so you will pay 1.25% additionally to the government because you are not grabbing dollar from the foreign while you are exporting your goods to the foreign	Transcription 1, P 54

(continued)

Table 9.1 (continued)

Significant statements	Address
Yes, the next thing is the Border closure. Like if I talk about the Southeast Asian countries like Russia, Moscow, Uzbekistan, Tajikistan, Azerbaijan, there we have a business but only violent shipment through Afghanistan	Transcription 1, P 54
However, if the situation is not good and stable so we are unable to supply those finish goods to the ground of sales	Transcription 1, P 54
Yes, as business students we keep in mind that time is money. Therefore, the same phenomenon is applied in pharmaceutical business, pharmaceutical practices	Transcription 1, P 54
That time is important because the lead-time for those countries for delivering the finish goods, if I talk about import so the duties and illegal shipment clearance time is much longer	Transcription 1, P 54
And most of the time, we were out of stocks because on the back we don't have stock to pile up there on the ground to be sold by our sales team. Therefore, the time is important	Transcription 1, P 54
The lead time is important that it should must be not more, when the situation were smooth in Afghanistan like this whole route for all the other countries depending on this route of Afghanistan, like Russia and the CIS countries	Transcription 1, P 54
I think the lead-time consisting around 25 days but now the recent shipment lead times to around 45–60 days	Transcription 1, P 54
So yes, time is money and definitely time matters in terms of timely delivery of the goods reflecting and securing of good revenue	Transcription 1, P 54
We are submitting sales number to the manufacturing plant for around 12 months that we will, we will lift up certain amount of these quantities in particular manner	Transcription 1, P 54
Therefore, they are already prepared and for at least three months, they built and pile up the stock in the FG finish good warehouse	Transcription 1, P 54
Now, the major challenge is the import of the raw material and the export of the finish goods from the factory gate to the distributor of the business partner, distributor warehouse that time thus affecting our revenue, this is a major thing	Transcription 1, P 54
What we have in control that is manufacturing time, yes no issue	Transcription 1, P 54
That is in our hand, might be to increase the number of labor, we can run the plant for 24-h	Transcription 1, P 54
We can expand our plant technology. Therefore, that is how we can increase our production	Transcription 1, P 54
That is in our control but I mentioned before the import and export delivery, these both are taking much time	Transcription 1, P 54
Every company desire to process quality material, not only in the shape of raw material but also in case of processing, technology, plant and office material between everything that matter	Transcription 1, P 55
In addition, I think it within my organization, CCL Pharma they maintain a proper decorum within the plant, office, and people are working in good environment and they are well-equipped and good material we are importing	Transcription 1, P 55

(continued)

Table 9.1 (continued)

Significant statements	Address
This is what an entrepreneur desires that they import the good material and even after conversion to finish goods they supply good product to the consumer	Transcription 1, P 55
That is how they can make the USP, the unique selling point that we are the company who import good quality as we have one branch of manufacturing in Vietnam and one certification we have in Canada	Transcription 1, P 55
Therefore, what we need to meet those criteria, requirement or those regulatory requirement to be fulfilled	Transcription 1, P 55
Therefore, for that kind of desire level, we need to import a good material process in a very good environment to supply good medicine in proper cool chain maintenance system to the end user that is consumer	Transcription 1, P 55

affect the process by creating delays in process. Time is important and usually processes takes longer time because of these regulations and should work on minimizing that time. Because delays in any single process affects the whole system of supply chain of pharmaceutical firms (Ghauri et al. 2022).

9.4.3 Product Expertise

Due to lack of product knowledge, it affects the pharmaceutical supply chain and results as operational inefficiencies. It is high in cost to develop such practice but it lift ups the efficiency of firms operations as by the help of such practice you would have the product knowledge and control in the markets (Maio et al. 2022).

9.4.4 Continuous Forecasting

Researcher finds out that due to inexperienced situations, which are experienced first time can be challenging and affects the operations of supply chain of pharmaceutical firms. Managers of firm can initiate such approach to overcome such challenges by maintaining proper stock levels all the time and go with more advance real time forecasting tools to avoid such inefficiencies. This can be opt as innovative approach (Jiang et al. 2019).

Table 9.2 The significant statements

Significant statements	Formulated meanings
So the major issue, what we so far faced like in few countries where our major contribution in sales, which are coming from are selling in PKR in our local currency but our import, the raw materials are in dollars. (Transcription 1, P 53)	Manager felt issue that transaction of money in different currencies affects the business revenue
So when we score that revenue in PKR and selling in PKR. Then when we convert in the open market to the dollar, so that hurt our profitability and definitely the supply chain. (Transcription 1, P 53)	Manager raises the issue by selling in local currency and buying in dollars effects business revenue
Like in the current economic situation as I mentioned before that the LC was stop by the Ministry of Finance Pakistan, that they have imposed sanctions that no one can issue the major and the big volume LC because of the inflation and all that. (Transcription 1, P 53)	Manager mentions that business gets ineffective due to government policies and regulations
So this is the factor which majorly influencing the import of raw material because if we are unable to import the raw material so how can we convert it to finish good and how can we supply to the field of sales and how can we secure our business revenue as well as profitability of the principal. (Transcription 1, P 53)	Manager felt that government rules majorly affects the supply chain process and results in low revenue
Actually, you know, I myself as a business student, there are factors which majorly influencing the business like some of which are in the grip of the internal principle. (Transcription 1, P 53)	Manager shares by experience that internal principles effects the business operations
So all these factors effect and what I mentioned before the major challenge is the economy of the country to that is one thing. (Transcription 1, P 53)	Manager mentions that economical conditions of a country effect the business process
Therefore, the next thing is that I mentioned before that our major sales are coming from Sri Lanka and Afghanistan. (Transcription 1, P 53)	Manager mentions the places of operations
In Sri Lanka you can see the same problems. They are facing the economical crisis and in Afghanistan in last August, the regime change leads to the major breakthrough and economical crisis as well as the LC's opening. (Transcription 1, P 53)	Manager has experienced the business loss in revenue due to the economical crisis of business countries

(continued)

Table 9.2 (continued)

Significant statements	Formulated meanings
What condition Pakistan today is passing that it is passed by Afghanistan even still the financial institution are closed, so that what it hurts that not only the pressure on the import business to import those raw material but as well as selling those materials underground in the field of sales. (Transcription 1, P 53)	Manager mentions the trade business is badly affected by the regulations of country
So definitely, we are unable to even get dollars through the legal channels. (Transcription 1, P 53)	Manager says that it is hard to sell products in dollars
So ultimately this is one thing, the second thing which I have observed as a business student (supply chain), that even Pakistan is now imposed a new duties and shipments or those process in PKR like in Afghanistan if I have got order of 56 million PKR, so now I'm unable to grab that money through the legal channels. (Transcription 1, P 53)	Manager says that business is affected by the new rules made by the government authorities
So what I need to I should have that money to supply that drug like that product that finish good because I have a team there that needs to supply that. (Transcription 1, P 53)	Manager says that one delay in process directly affects the whole process of business
Pakistan government is not cooperating and even now, they impose a new tax of 1.5% against the invoice generated. (Transcription 1, P 54)	Manager says that due to the new policies of taxation business is affected
If you receive the payment in the banks against the export in Afghanistan so you will pay 1.25% additionally to the government because you are not grabbing dollar from the foreign while you are exporting your goods to the foreign. (Transcription 1, P 54)	Manager says that government policies regarding taxation effect the business operations
Yes, the next thing is the Border closure. Like if I talk about the Southeast Asian countries like Russia, Moscow, Uzbekistan, Tajikistan, Azerbaijan, there we have a business but only violent shipment through Afghanistan. (Transcription 1, P 54)	Manager felt that border closure is the reason in effecting business supply chain
However, if the situation is not good and stable so we are unable to supply those finish goods to the ground of sales. (Transcription 1, P 54)	Manager says if routes are closed so it effects the business process
Yes, as business students we keep in mind that time is money. Therefore, the same phenomenon is applied in pharmaceutical business, pharmaceutical practices. (Transcription 1, P 54)	Manager tells that time is essential part of supply chain in pharmaceutical business

(continued)

Table 9.2 (continued)

Significant statements	Formulated meanings
That time is important because the lead-time for those countries for delivering the finish goods, if I talk about import so the duties and legal shipment clearance time is much longer. (Transcription 1, P 54)	Manager felt due to the strict policies, goods are delivered late and effect the whole process
And most of the time, we were out of stocks because on the back we don't have stock to pile up there on the ground to be sold by our sales team. Therefore, the time is important. (Transcription 1, P 54)	Manager felt that due to the long clearance time we get out of stock that effects the business process
The lead time is important that it should must be not more, when the situation were smooth in Afghanistan like this whole route for all the other countries depending on this route of Afghanistan, like Russia and the CIS countries. (Transcription 1, P 54)	Manager says that the lesser the time to purchase raw material the effective the business will get
I think the lead-time consisting around 25 days but now the recent shipment lead times to around 45–60 days. (Transcription 1, P 54)	Manager has experienced the business process take longs time than the usual time because of the route problem
So yes, time is money and definitely time matters in terms of timely delivery of the goods reflecting and securing of good revenue. (Transcription 1, P 54)	Manager says that if business process takes longer time it creates ineffectiveness
We are submitting sales number to the manufacturing plant for around 12 months that we will, we will lift up certain amount of these quantities in particular manner. (Transcription 1, P 54)	Manager says proper procurement of goods makes the business process effective
Therefore, they are already prepared and for at least three months, they built and pile up the stock in the FG finish good warehouse. (Transcription 1, P 54)	Manager says that extra stock keeping help operations run smoothly
Now, the major challenge is the import of the raw material and the export of the finish goods from the factory gate to the distributor of the business partner, distributor warehouse that time thus affecting our revenue, this is a major thing. (Transcription 1, P 54)	Manager says that delays in process effects the business supply chain
What we have in control that is manufacturing time, yes no issue. (Transcription 1, P 54)	Manager say if procurement of goods takes less time automatically business gets better as other processes are in our hands
That is in our hand, might be to increase the number of labor, we can run the plant for 24-h. (Transcription 1, P 54)	Manager says that manufacturing of goods is effective if raw material is available in timely manner

(continued)

Table 9.2 (continued)

Significant statements	Formulated meanings
We can expand our plant technology. Therefore, that is how we can increase our production. (Transcription 1, P 54)	Manager felt that if raw material is available at given time other process would get effective
That is in our control but I mentioned before the import and export delivery, these both are taking much time. (Transcription 1, P 54)	Manager says that trading of goods takes longer time period that affects the business process
Every company desire to process quality material, not only in the shape of raw material but also in case of processing, technology, plant and office material between everything that matter. (Transcription 1, P 55)	Managers have mentioned that is good material is bought and processed so it positively affects your business
In addition, I think it within my organization, CCL Pharma they maintain a proper decorum within the plant, office, and people are working in good environment and they are well-equipped and good material we are importing. (Transcription 1, P 55)	Manager believes that good qualities and assurance effect positively to supply chain of pharmaceutical
This is what an entrepreneur desires that they import the good material and even after conversion to finish goods they supply good product to the consumer. (Transcription 1, P 55)	Manager say that businessperson should acquire quality product and services to make their business process effective
That is how they can make the USP, the unique selling point that we are the company who import good quality as we have one branch of manufacturing in Vietnam and one certification we have in Canada. (Transcription 1, P 55)	Manager believes if good quality and service is used and implemented in your business supply chain process it brings out positive change
Therefore, what we need to basically meet those criteria, requirement or those regulatory requirement to be fulfilled. (Transcription 1, P 55)	Manager tells that run business according to the updated rules and policies
Therefore, for that kind of desire level, we need to import a good material process in a very good environment to supply good medicine in proper cool chain maintenance system to the end user that is consumer. (Transcription 1, P 55)	Manager says that good quality can be maintained if goods are acquired according to updated versions of quality keeping technology
Therefore, material overall should be very good not only in shape of finish good supply to the consumer but also in case of import raw material. (Transcription 1, P 55)	Manager suggests to always buying good material as it effects the business operations

(continued)

Table 9.2 (continued)

Significant statements	Formulated meanings
I mentioned that cost definitely, if I am importing good quality material, raw material then all clearance duty like custom cost in shape of converting those raw material in finish good and then cost to deliver those finish pharmaceutical goods to patients. (Transcription 1, P 55)	Manager says that acquiring good services and desired quality you have to pay high cost
So all aspects and all multiple processes cost exactly, does matter. (Transcription 1, P 55)	Manager believes that cost effects the business operations
In addition, this is vital part of the any product in shape of importing the raw materials and conversion cost, as well as exporting those medicine at affordable price. (Transcription 1, P 55)	Manager believes that proper costing while acquiring and selling affect the business process
Like if I import any product with a very expensive price, because if thing will be good, the price will definitely be very high. (Transcription 1, P 55)	Manager felt to maintain quality you have to buy good quality material in high price
Like if I import any product with a very expensive price, because if thing will be good, the price will definitely be very high. (Transcription 1, P 55)	Manager believes prices reflect the business process
We can secure the employee salaries, and we need to compensate all these things including cost. (Transcription 1, P 55)	Manager believes that proper costing effects business process
It does matter and not only in shape of raw material importing but also offering the finish good to the end-user there that is patient at a very affordable cost. (Transcription 1, P 55)	Manager says that costing should be done in such manner that patient can afford it in your market
Most of the drugs are life-saving drugs, hypertension, or diabetes. So that's how we need to keep a price capping. (Transcription 1, P 55)	Manager says that prices of drugs should be done according to the whole operation of providing that drug

Source Author

9.4.5 Technological Advancement

Due to lack of technology operations of supply chain gets inefficient in pharmaceutical firms and if the pharmaceutical firms invest in new technologies with time so it will result in bringing efficiencies to the operations of supply chain. This can be used as innovative approach by installing new technologies to avoid operation inefficiencies (Zaman et al. 2023a).

Table 9.3 Meaning formulation

Formulated meanings	Initial themes
Manager mentions that economical conditions of a country affect the business process	Manager feels that economical conditions of every country affect the business process
Manager has experienced the business loss in revenue due to the economical crisis of business countries	
Manager tells that time is essential part of supply chain in pharmaceutical business	Manager experience that time is important and usually processes takes longer time and should work on minimizing that time
Manager felt that due to the long clearance time we get out of stock that affects the business process	
Manager says that if business process takes longer time it creates ineffectiveness	
Manager says that trading of goods takes longer time period that affects the business process	
Manager felt that time affects the SC process	
Manager believes that time is important factor and should be considerate while conducting business	
Manager says that time and cost should be considerate while conducting business as it effects the business operations	
Manager feels that time changes and decisions should be taken according to that	
Manager share the essence of time that time is more important even though it take cost to minimize operation time to enhance operation effectiveness	
Manager mentions that business gets ineffective due to government policies and regulations	Manager feels that government regulations are important while conducting business but it negatively affects the business process
Manager felt that government rules majorly affects the supply chain process and results in low revenue	
Manager mentions the trade business is badly affected by the regulations of country	
Manager says that business is affected by the new rules made by the government authorities	
Manager says that government policies regarding taxation effect the business operations	
Manager says that regulations of country should consider peoples income so they can afford the essential good	

(continued)

Table 9.3 (continued)

Formulated meanings	Initial themes
Manager felt that government regulations towards acquisitions of some materials affect the business	
Manager believes that regulation affects the whole process	
Manager says that business operations need to process according to regularities body	
Manager says that regulatory bodies effect the business operations	
Manager says that when company follows WHO guide lines it makes the regulatory requirements fulfilled as well	
Manager believes that regulatory requirements affect the business process of pharmaceutical sectors	
Manager says to ensure the quality of products, government regulations should be taken	
Manager says to sustain business effective you have to run according to government regulations	
Manager says that regulations effect the business operations	
Manager says that due to the new policies of taxation business is affected	Manager has experience that government policies badly affect the process by creating delays in process
Manager felt due to the strict policies, goods are delivered late and affect the whole process	
Manager tells that run business according to the updated rules and policies	
Manager tells that government policies affect the whole process of pharmaceutical goods	
Manager felt that covid affected the business supply chain as new policies and the authorities made regulations	
Manager tells about new policies of banning products from foreign affect the process	
Manager tells that it is important to follow with every policy	
Manager says that following international standard affects the business positively	
Manager says that policies affect the business operation and forecasting should be done to avoid time delays	

(continued)

Table 9.3 (continued)

Formulated meanings	Initial themes
Manager mentions that policies of different countries affect the business	
Manager believes that following international standard increases operations efficiencies	
Manager felt that following international standard help in pertaining efficiency	

Source Author

9.5 Conclusion

The purpose of this study was to assess the entire pharmaceutical supply chain within Pakistan. The known issues can be viewed as innovational approaches implemented to amend the supply chain systems of pharmaceutical companies that have inefficiencies in their operations.

This study fills a gap in the literature on supply chain management in pharmaceutical companies in the Asian region of Pakistan. It also contributes to the literature by examining the full extent of the pharmaceutical supply chain, using pharmaceutical companies as central organizations. Previous book chapter examining aspects of the pharmaceutical supply chain focused primarily on the upstream part of his pharmaceutical supply chain, including pharmaceutical manufacturers (Narayana et al. 2014).

The current investigation identifies four key areas of inefficiency affecting his pharmaceutical supply chain in Pakistan: Government regulations, continuous forecasting, product expertise, and technological advancements. In addition, this paper focuses on the issues observed in Pakistan, providing greater clarity on pharmaceutical supply chain processes applied in Asian contexts and allowing generalization of research findings.

9.5.1 Insights and Implications Post-Covid Practice

This study is intended for exploration and gives useful farther theoretical understanding to development of supply chain strategies. The findings places four critical areas of intercession needed across the pharmaceutical supply chain. These findings may help us understand the operational inefficiencies facing by pharmaceutical companies and guide us to appropriate innovative solutions that can improve levels of efficiency and effectiveness (Ishizaka et al. 2023). This study examines a pharmaceutical company's supply chain in the context of Pakistan. The results of the survey therefore provide information on ineffective practices or best patterns that can be

Table 9.4 Cluster and emergent themes

Initial themes	Theme clusters	Emergent themes
Manager feels that government regulations are important while conducting business but it negatively affects the business process	Importance of following rules and procedures	Government regulations
Manager has experience that government policies badly effect the process by creating delays in process		
Manager experience that time is important and usually processes takes longer time and should work on minimizing that time	Competing against time	
Manager felt that delay in any single process affects the whole system		
Manager says that transit time should be less otherwise, it will affect the business		
Manager has experience that long routes and border closures effects the business process		
Manager feels that economical conditions of every country affect the business process	Awareness of economical conditions	
Manager has experience that converting currency affects the business revenue and system		
Manager believes that high cost affects the business process	Cost of the business	Product expertise
Manager experience that pricing of finish goods should be according to quality and process		
Manager suggest that product expertise helps bringing efficiency in the system	Knowledge of product and market	
Manager felt if goods are bought in proper time, it makes the system effective		
Manager believes that future forecasting should be on advance level to make better decisions	Overseeing the future opportunities	Continuous forecasting
Manager experience that inexperienced situations affects the business, as they are new to tackle		
Manager felt that availability of goods is important to make system more effective	Maintaining stock levels	
Manager felt that extra stock keeping helps in urgent requirement issues		
Manager believes that technological advancement can make the business more effective and efficient, as it will smoothly run the business in less time	Investing in new technology	Technological advancement
Manager believes when good material is purchased and processed so it positively affects the business process	Maintaining quality in operations	
Manager suggests if quality is maintained then it results as effective and efficient business flow		

Source Author

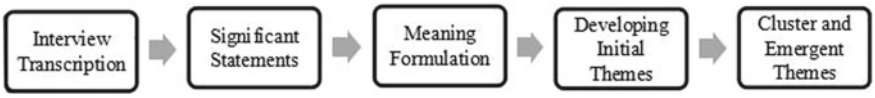

Fig. 9.2 Steps involve in transcription. *Source* Author

applied in Pakistan. This study focuses on drug supply chain practices in pharmaceutical companies. It is also worth investigating and studying the pharmaceutical supply chains of other healthcare institutions to understand the impact produced by the actions of other stakeholders. While this study provides insight into the factors that can influence the performance of a pharmaceutical business, focusing on a specific pharmaceutical supply chain can add additional information, based on that can make research that is more reliable (Zaman et al.). Future research is needed on the pharmaceutical supply chain strategies that are followed by other different Asian countries and to the opposite side of Asian borders. Additionally, future studies may improve the generalizability of the findings when conducted in other industries, such as the food industry.

9.5.2 Limitations

Given the relatively high workload of professionals working in pharmaceutical companies, some potential participants were reluctant to participate in this study. Furthermore, the study only focused on pharmaceutical companies, excluding professionals operating in the supplier and consumer sectors. Another obstacle encountered, especially in the data collection process, is related to geographical distance, the researcher only approached potentially reachable participants. Finally, a final limitation of this study arose from how data analysis was performed as the thematic analysis was conducted by the researcher.

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Chapter 10
Supply Chain Resilience During Pandemic Disruption: Evidence from the Healthcare Sector of Pakistan

Evaluating Demand and Supply Chain Resilience

Syed Imran Zaman, Sharfuddin Ahmed Khan, Sherbaz Khan, and M. Affan Badar

Abstract The research aims to investigate the impact of supply chain resilience in the healthcare supply chain of Pakistan when experiencing the COVID-19 pandemic disruption. The study uses a qualitative approach. The interview method is selected for data collection. Population of the research is the healthcare sector of Pakistan. A sample of three participants is chosen for this study. Findings: The study finds six different themes as the key strategies of supply chain resilience in COVID-19 disruption namely, cost-effectiveness, collaboration, flexible supply chain strategies, conflict management, future planning, and self-medication. Implications: The research implies focusing on these factors in order to strengthen the supply chain network so that organizations do not have to face risks and disruptions during a crisis or pandemic period.

Keywords Supply chain resilience · Supply chain disruption · COVID-19 pandemic · Pandemic disruption · Healthcare sector · Pakistan · Evaluating demand

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10.1 Introduction

10.1.1 Book Chapter Overview

The COVID-19 epidemic has painfully brought to light the need to reevaluate supply chain management as well as the practices followed in healthcare sectors, corporate structures, and the lifestyles of individuals (Mubarik et al. 2021). The year 2020 saw the common prevalent themes in the media, public policy debates, and daily conversation: limitations in the supply of various items (Khan et al. 2023b). Demand patterns significantly altered due to the sudden outbreak of COVID-19 (Ferdous et al. 2022). Lockdowns and bare shop shelves were seen on the supply side (Miao et al. 2022). Prior to the epidemic, the main focus was on creating supply chains that were flexible, lean, sustainable, environmentally friendly, optimized, and effective Al-Odeh et al. 2021; Badar et al. 2013). These issues have not been neglected throughout the epidemic, but the main concern have significantly shifted.

According to Toba et al. (2008), the process of supply chain is very important as it enables the provision of healthcare treatments and other services to the patients. In order to bring products and services to the patient, who actually avails the services of the healthcare industry, supply chain is a vital and life-saving component (Rakovska and Velinova 2018). In contrast to a business setting where SC interruption might result in lost money, healthcare is significantly more important since lives are at danger (Getele et al. 2019). Supply chain management in the healthcare industry is often a very complicated and disjointed process (Saviano et al. 2014; Mubarik et al. 2021). Regardless of how severe the disruption events are, companies must adopt groundbreaking precautions to avoid or lessen the damage they pose (Mubarik et al. 2022). Hence, the study focuses on the supply chain resilience in the healthcare sector Pakistan during the pandemic disruption (Khan and Zaman 2023).

Supply chain disruptions are considered as a combination of unforeseen circumstances and their effects, which significantly endanger the movement of materials and regular company operations (Khan et al. 2022c). As a technique to guard against a number of threats and disruptions occurred in supply chain, supply chain resilience has emerged as a central concept in the literature on supply chain management (Miao et al. 2022). Pandemic disruption generates specific SC issues that are challenging to defend (Ivanov 2020; Govindan et al. 2020). Pandemics expose the weaknesses of supply chain practices followed in the world because to factors like China's focus of PPE manufacture and unparalleled requirement of the world (Bradsher 2020; Khan et al. 2022b).

It is important to note that pandemics are acknowledged in the book chapter on supply chain risks in a number of studies (for instance, Calnan et al. 2017), less focus was placed on the way resilience might lessen disruption from pandemics (Rubbio et al. 2019; Zaman et al. 2023b), particularly in the healthcare sector (Syahrir et al. 2015). Since the COVID-19 pandemic was the first of its kind encountered and was not anticipated by the general public, no comparable studies can be found and the majority of the studies in this area is still in its early stages. Numerous scholars

studying various issues that are affected by the pandemic right now, and there will be a lot of papers in upcoming years to come that will also be a significant contribution in describing supply chain resilience especially in healthcare sector. The literature assessment is obviously preliminary and selective due to the extremely dynamic growth at the time this study was produced (Zaman et al. 2023a).

Hence, there is a room to investigate the important topic of supply chain resilience during the ongoing COVID-19 epidemic. Also, there is no study found in a literature that has focused on supply chain resilience in health sector in the context of Pakistan, hence, the study is filling the gap in literature by answering the following questions:

1. How is Supply chain resilience revealed in healthcare supply chain of Pakistan when experienced the COVID-19 pandemic disruption?
2. What are the lessons learned from the tests on resilience as a result of the COVID-19 pandemic?

From the above details, the objectives of this chapter is to:

- Explore supply chain resilience in healthcare supply chain of Pakistan during the COVID-19 pandemic disruption.

10.2 Theoretical Background

10.2.1 Supply Chain Resilience

According to Brandon-Jones et al. (2014), supply chain resilience can be defined as the capacity of the system to get back to the original condition, in a satisfactory duration of time, after facing disruption. Resilience helps identify the most vulnerable links in the network and strengthen them so that, in the case of a future disruption, the system do not have to experience the same and handle it with ease (Khan et al. 2021). The supply chain is kept moving with supplies and information thanks to the supply chains' resilience (Mubarik et al. 2021). Even the smallest material holdup in any supply chain of the company has a significant time and financial impact (Miao et al. 2022).

Since both notions pertain to an organization's or supply chain's capacity to respond to unforeseen events and environmental changes, many scholars contend that resilience and flexibility are connected (Khan et al. 2022c). Resilience is connected to the range of planned or spontaneous organizational responses to shocks, much like flexibility (Mubarik et al. 2021). One aspect of supply chain resilience is its capacity to accommodate fluctuations in delivery as well as fluctuations in volume, fast product design alterations, and a range of marketing activities (Miao et al. 2022). Market sensitivity is an important element in supply chain's resilience to comprehend and respond to customer demand while lowering the likelihood of supply deficiencies or interruptions (Kopanaki et al. 2018; Jiang et al. 2019).

Scholars, professionals, and policymakers are paying close attention understand the impact of COVID-19 epidemic in an effort to strengthen the supply chain resilience (Mubarik et al. 2022). Transportation networks and related supply chain operations are seen as having high resilience (Aydin et al. 2018; Ilbeigi 2019). More than ever before, academics are researching many facts of the supply chain resiliency (Khan et al. 2023b). The most widely read essay by Ivanov (2020) sought to foresee the outcome impact of a pandemic on supply chain efficiency. The article investigated the duration of supply chain disruption through the perspective of resilience the supply chain may endure as well as the duration of recovery process. It was discovered that several crucial elements, such the opening and closure of facilities, the influence of time, interruption propagation time, and lead time on the supply chain resilience was substantial.

According to Govindan et al. (2020), in the healthcare setting, the requirement to provide critical care skyrockets when the world was experience COVID-19, and effective hospital demand management might lessen the COVID effects. The book chapter suggested a strategy for prioritizing patients in order to maximize hospitalization and intensive care provision. In order to increase the supply chain resilience, Remko (2020) split the pandemic supply chain risks by categorizing into three different groups, which are control, demand, and supply risks.

10.2.2 Strategies to Overcome Supply Chain Resilience

COVID-19 pandemic played a significant role in causing major disruptions in supply chain management (Ivanov 2020) and has been regarded as the biggest risk factor in breaking numerous global supply chains (Araz et al. 2020; Queiroz et al. 2020). However, the COVID-19 was not the only crisis that was experienced by the industries. A number of instances are available in the history that caused a major supply chain disruption, for instance, Tsunami in Japan in the year 2011 that had a global impact of supply chain. Other outbreaks such as Ebola virus, acute respiratory syndrome (SARS), etc. (Green 2012) were also worth mentioning that instigated a number of authors to conduct the study (Dasaklis et al. 2012; Calnan et al. 2017; Mubarik et al. 2023).

For instance, the study of Tan and Enderwick (2006) provided recommendation for the organizations to reevaluate their supply chain practices in order to understand the major issues and bottlenecks and enable slack that can dodge the delays as well as the possible issues expected to happen. In order to avoid risk and uncertainties, organizations can also try to keep buffer stock or safety inventory (Khan et al. 2023a).

Following a thorough study of the literature on the effects of COVID-19 epidemic on supply chain, Queiroz et al. (2020) suggested a supply chain framework that can be followed at the time of COVID-19 pandemic based on their results. According to Queiroz et al. (2020), the primary book chapter topics for supply chain management during disease pandemic is sustainability. In addition to emphasizing sustainability, it is crucial to leverage technological and digital methods, such as data analytics or

digital manufacturing, to enhance processes and supply chain management during such epidemics or pandemics (Miao et al. 2022). Different components of supply chain resilience, such as recovery, ripple effect control, readiness, and adaptation, make up the majority of the recommended study purpose (Khan et al. 2021).

According to the study of KPMG (2022), since COVID-19 significantly disrupted the supply chain, executives must now right-size their operations and embrace digital capabilities that shield supply networks from further disturbances as we move into the post-COVID-19 world companies across all sectors are increasing their investments in cutting-edge innovation, which have shown to be the driving force for the company (Khan et al. 2022b). These technologies range from block-chain to artificial intelligence (AI), machine learning, and intelligent automation (Khan et al. 2022c).

Majumdar et al. (2021) carried out a study with the goal of prioritizing risk reduction tactics for supply chains in sustainable apparel. A number of risk mitigation techniques and different risk types were examined. The most crucial method for disruption risk reduction was discovered to be supply chains' increased agility. Numerous green sourcing options, adaptable capacities, adoption of green practices, coordination, and teamwork were also shown to be effective tactics.

In context of healthcare industry, Rowan and Laffey (2020) provided three different strategies to overcome supply chain resilience caused by COVID-19 disruption. These strategies include enhancing lines of communication by familiarizing websites, the usage of mobile applications to facilitate inventory management and personalized manufacturing of PPEs. Govindan et al. (2020) in their book chapter presented an analysis and framework to show how to make the weakest and vulnerable patients the hospitals' priority, for instance, high blood pressure patients, diabetic patients, those who need restricted care and those needing home care during COVID-19. The major solution proposed for the resilience was to ramp up the production. Iyengar et al. (2020) proposed openly sourcing of ventilator production, in which businesses not manufacturing ventilators may assist the manufacturing firms of ventilators.

10.2.3 Theoretical Perspective—Resource Based View

In terms of the theoretical view of the book chapter, the study uses a resource-based approach to the book chapter. Finding the origins of achieving competitive edge is a key study area in strategic management (Porter 1985). Considering the perspective of a resource-based approach, a firm's ability to use particular resources and competencies that it either possesses or has the potential to acquire will provide it a competitive edge. By examining these assets and skills, it becomes clearer how businesses outperform rival businesses (Nandi et al. 2020). The important assets or belongings of a company that can be accessed to or owned by are the resources. Such resources can discriminate between intangible resources like information exchange and concrete resources like infrastructure. Furthermore, unless they are combined

with other resources to create capabilities, individual resources may not result in a competitive edge (Brandon-Jones et al. 2014; Zaman et al.).

The Resource based view is useful for comprehending, framing the way supply chain resilience may be utilized, and disruption risks can be decreased (Cheng and Lu 2017). For example, resource buffering and bridging minimize risk and lessen the effect of disruptions, while resource reconfiguration can take advantage of supply chain resilience (Ambulkar et al. 2015; Jiang et al. 2023). Additionally, a number of authors link resources and skills to supply chain resilience measurements that have a favorable influence on supply chain resilience and provide competitors an edge (Rajesh 2019). In order to determine when and in what ways supply chain organizations produce supply chain resilience, the present study use Resource based view.

10.3 Methodology

The two main choices of book chapter that are often most frequently employed for data collecting are quantitative and qualitative approaches. In order to understand the impact of supply chain resilience in healthcare supply chain, the study will use qualitative method. Qualitative techniques emphasis on comprehension, meaning, nature observations, and proximity to data from an internal perspective hence, this method is more convenient and suitable for the study.

The major advantage of using a qualitative method in a book chapter is that it includes all those information and facts that are often overlooked in quantitative approach. Given that the present book chapter examines the supply chain resilience focusing on the perceptions, views, ideas, and opinions of the supply chain managements, it seems challenging to quantify the perception and views, hence, a qualitative method seems more effective in achieving the goals of this book chapter. Using qualitative approaches, the author can comprehensively examine views, dynamics, and challenges of supply chain resilience in order to grasp perspectives and opinions of the issues.

10.3.1 Data Collection

The aim of the book chapter will be achieved by collecting the data with the help of interviews. The supply chain managers will be the participants of the book chapter and they will provide a detailed information regarding the supply chain resilience.

10.3.2 Sampling and Sample Size

The population of the book chapter is the health care sector of Pakistan. A sample size of three participants is chosen for this study. In addition, purpose sampling method is used which is one of the types of non-probability sampling method.

10.3.3 Thematic Analysis

In order to analyze the data, the author will use thematic analysis. The versatility of thematic analysis is one of its distinctive characteristics, which may be utilized within a number of theoretical structure and epistemological frameworks and used to a different type of book chapter topics, strategies, and sample sizes. When thematic analysis is utilized, the topic must "explain the bulk of the data" in order to provide content. To put it another way, a lot of material, or data, is needed. This is so because, despite the fact that a single sentence might be important, it may not accurately capture the entire narrative. This is particularly true when the goal of the study is to understand and identify connections among the various data coming from various student groups. As a result, the author must present and explain a substantial number of data.

To locate, comprehend, characterize, and express the experiences of satellite nursing academics as they encounter them, as well as to identify emerging themes and their intertwined linkages, the author employed Valley and King (1978) technique of data analysis, which is also known as a challenging and robust qualitative approach.

10.4 Data Analysis

The data analysis for the book chapter was conducted after completing a series of steps. After completing all interviews, the author overviewed the transcripts numerous times to comprehend the context of the episodes for every respondent, but also avoided developing any notions, structures, or theories as a result of reviewing the data initially in the process. In the second step, the author took out around 97 significant statements regarding the supply chain resilience as seen in Table 10.1.

In the next step of analysis, the principal author retrieved and developed the meanings of each major remark, and verified and debated each one. The author made an effort to design the meanings to allow them to encompass respondents' statements with various profiles and modes of expression in light of the multiplicity of contexts. While maintaining conformity to the original descriptions, this necessitated a certain amount of abstraction. Nearly 97 defined meanings are shown by instances in Table 10.2.

Table 10.1 Key indicators, *source* Author

S. No.	Significant statement	Address
1	Price are fluctuating every second but we must have to buy them as it belongs to the patient end not to the user end	Transcript 1 P40
2	Our sub store, nursing staff, support services staff are user end but the patient end is immediate on which particular things applied	Transcript 1 P40
3	We scratch-up, dig-up number of vendors of that particular product. We visited market and also follow COVID protocols and line-up all the things	Transcript 1 P40
4	We realized that our strategies must have to substitute the suppliers of particular items	Transcript 1 P40
5	We are basically in basement	Transcript 1 P40
6	For ventilation we go at first floor and where at the same time COVID patients are moving for treatment's	Transcript 1 P40
7	Our family is getting disturbed from that activities because we are all time surrounded by COVID patient's	Transcript 1 P40
8	Trying to build ourselves in that environment which is very difficult and very important	Transcript 1 P41
9	We were not ready for such kind of loss and neither economically nor professionally	Transcript 1 P41
10	Those companies whose supply chain was not strong were closed down and people became unemployed	Transcript 1 P41
11	Its impact is so dangerous	Transcript 1 P41
12	There are many health care centers like Tabba heart institute, South city, Liaquat national, Agha Khan. They are ready for every kind of disaster which going to hit the country	Transcript 1 P41
13	They have planned for the next 30th years or not only planned but in the next 30 years, the things that have happened will happen again	Transcript 1 P41
14	The supply chain is a very strong, wide, diversified field and every department plays its role	Transcript 1 P41
15	Supply chain plays various and vital role to accommodate good feedback	Transcript 1 P41
16	Due to pandemic many supply chain matters line up and dead procedures, problems were re-awaked	Transcript 1 P41
17	Housekeeping, our nursing staff. In addition, our COVID staff are very important	Transcript 1 P41
18	We have to face many problems during covid	Transcript 1 P42
19	It made us very cost-effective	Transcript 1 P42
20	Items are important but items are not available	Transcript 1 P42

(continued)

Table 10.1 (continued)

S. No.	Significant statement	Address
21	There were very serious patients of COVID including both male and female, if we only talk about our nursing staff they gave it over all, they were with the COVID patients day and night	Transcript 1 P42
22	Our housekeeping staff performed very well and stay resilient among all covid duration	Transcript 1 P42
23	I want to say that not everything is perfect, everything thing needs perfection in coming days but the things we have learned after COVID hit Pakistan is that humanity cannot defeat the nature	Transcript 1 P42
24	Many companies were switched themselves to online in result many expenses were cut down economically	Transcript 1 P42
25	Many companies and their departments which were not at sustainable position were collapsed and their people became unemployed	Transcript 1 P42
26	Many good companies went through unemployment, the main reason behind that is their organizational structure was not good enough	Transcript 1 P42
27	When your organizational structure is not good, you have to face such kind of problems in your companies	Transcript 1 P42
28	It means this is our key lesson that our first priority is to make our organizational structure strong	Transcript 1 P42
29	If we study history we will find that if there is no movement of supply chain then it will be pretty sure that company will completely destroy in coming two to three years	Transcript 1 P42
30	The main lesson in that is we should not be afraid from these kind of situations and just try to follow rules like we know what the safety principals are	Transcript 1 P42
31	If we feel any kind of symptoms we should immediately contact to the doctor not rely ourselves on self-medication	Transcript 1 P42
32	We should keep ourselves self-medicated but at certain level when we feel now there is no advantage of self-medication you should immediately concern to the doctors	Transcript 1 P43
33	This pandemic shone a bright light on the weakness and cracks of supply chain with in the health care sector	Transcript 2 P43
34	COVID left the health care sector in trouble. Hospital's overloaded and overflowed	Transcript 2 P43
35	Critical items also interrupted and basic elements getting shortage in the market (i.e. PPE's and testing kits)	Transcript 2 P43
36	Prices get boom double to triple	Transcript 2 P43
37	There are two kinds of relationship i.e. user end and patient end. The user end which is staff need to use that PPE but that usage is important for patient i.e. costumer end	Transcript 2 P43
38	In this event level of uncertainty is high, length of the disruptions is too long which also hits area geographically	Transcript 2 P44

(continued)

Table 10.1 (continued)

S. No.	Significant statement	Address
39	Supply chain is not only about supply it also about demand	Transcript 2 P44
40	To strengthen or stabilized our supply chain for future disruptions. First of all to identification of challenge	Transcript 2 P44
41	If we talk about Pakistan the conditions is quite much worse as compare to other countries because of weak healthcare system and strategies	Transcript 2 P44
42	In Pakistan this pandemic become a reason to re-awake the dead practices and weak healthcare structure	Transcript 2 P45
43	As well as our organization is concern, we built fully ERP system before arrival of this pandemic	Transcript 2 P45
44	This pandemic specially made us cost effective because required equipment's are needed but not available	Transcript 2 P45
45	We scratch-up multiple clients and found the most suitable price	Transcript 2 P45

The second stage of abstraction in Colaizzi's technique occurs as themes are created from the defined meanings. Here, the author organized the linked formed meanings into groups, allowing each meaning to belong to just single group. Hence, the initial theme for formulated themes are emerged in Table 10.3.

Below table provides an illustration of how combining earlier concepts might lead to different emerging themes regarding supply chain resilience, and total five emergent themes can be found in Table 10.4.

10.4.1 Discussion

According to the analysis above, six different themes were found that are identified as the key strategies of supply chain resilience in COVID-19 disruption. To strengthen or stabilized the supply chain for future disruptions, it is important to understand cost effectiveness, collaboration, flexible supply chain strategies, conflict management, future planning and self-medication.

Resilience of an economic system without respect for cost is inadequate. Resilient supply networks may not always be those with the lowest prices (Jamil et al. 2022). Disruptions to the supply chain should be reduced as much as possible. Cost effectiveness has been noted as a characteristic of robust systems, and resilient supply chains must prioritize cost reduction through quick and efficient coordination. Additionally, supply chain resilience should necessarily be seen as the capacity to not only a risk management factor but it should be the method to respond to the rivals in cost effective ways, giving the company a competitive edge (Yao and Meurier 2012; Khan et al.). The findings of the study match the result of Yang and Xu (2015) who

Table 10.2 Significant statement, *source* Author

S. No.	Significant statements	Formulated meanings
1	Price are fluctuating every second but we must have to buy them as it belongs to the patient end not to the user end	1. Price factor involve in order to fulfill the requirement 2. That events make us cost effective 3. Shortage of supply occurs whenever disruptioncomes 4. We need to involve always in search of multiple suppliers
2	We scratch-up, dig-up number of vendors of that particular product. We visited market and also follow COVID protocols and line-up all the things	
3	It made us very cost-effective	
4	Critical items also interrupted and basic elements getting shortage in the market (i.e. PPE's and testing kits)	
5	Prices get boom double to triple	
6	This pandemic specially made us cost effective because required equipment's are needed but not available	
7	We scratch-up multiple clients and found the most suitable price	
8	The prices are also getting high due to dramatic increase in demand	
9	We faced the high cost on some items especially on PPE's	
10	We are basically in basement	1. We must have to face some personal issues when faced that kind of disruptions
11	For ventilation we go at first floor and where at the same time COVID patients are moving for treatment's	
12	Our family is getting disturbed from that activities because we are all time surrounded by COVID patient's	
13	There were very serious patients of COVID including both male and female, if we only talk about our nursing staff they gave it over all, they were with the COVID patients day and night	
14	During this disruption many people become unemployed, robberies also increased due to these unemployment's	
15	There are many health care centers like Tabba heart institute, South city, Liaqat national, Agha Khan. They are ready for every kind of disaster which going to hit the country	1. Every healthcare sector need good future forecasting

(continued)

Table 10.2 (continued)

S. No.	Significant statements	Formulated meanings
16	They have planned for the next 30th years or not only planned but in the next 30 years these things that have happened will happen again	
17	The main lesson in that is we should not be afraid from these kind of situations and just try to follow rules like we know what the safety principals are	1. Don't need to be afraid of natural disruptions 2. Always follow the safety precautions 3. Good organizational structure is very important for long time stability
18	If we feel any kind of symptoms we should immediately contact to the doctor not rely ourselves on self-medication	
19	We should keep ourselves self-medicated but at certain level when we feel now there is no advantage of self-medication you should immediately concern to the doctors	
20	In the initial stages we don't have medical and diagnosis facilities. Until government takes the responsibility of this work	
21	We must need to understand that no one in the world able to defeat the nature	
22	We need to follow proper precautions and act accordingly	
23	Firstly, I see many companies collapse in this pandemic because of weak organizational structure	
24	Some of them were start work from home specially HR department, supply chain department, admin department and other management departments	
25	Same as for COVID we must have to strictly follow the safety precautions	
26	We learn that in this scenario some organization moved towards employment rather than un-employment	

stated that when choosing the best ways to construct grain supply chain resilience against calamities, recovery cost is the crucial factor.

10.4.2 Findings

The findings also suggested that the collaboration and support are highly important in order to overcome disruption in supply chain operations and to be supply chain resilience. The support services department and procurement department performed well or resilient in this disruption, according to the result. The hospitals worked on inventory forecasting or planning and built strong housekeeping team in order to counter the existing condition. The findings related to the collaboration and support within organization compliments the theoretical premise that greater coordination along the supply chain enables businesses to respond swiftly to shifting supply and

Table 10.3 Formulated meanings, *source* Author

Formulated meanings	Initial theme
1. Price factor involve in order to fulfill the requirement 2. That events make us cost effective.3. Shortage of supply occur whenever disruptioncomes 4. We need to involve always in search of multiple suppliers	Interviewee try to explain the cost factor involving either shortage of items or prices boom dramatically. Which shows that if any disruption will occur we have to face these issues (i.e. shortage of important items either PPE's or machines, price fluctuation)
1. Trained staff is the basic need in order to perform resilient against disruptions 2. In these disruptions we need to stay positive and built ourselves in according to the situation 3. After-effects of any disruptionis remain at 30th years 4. It will repeat itself after some interval of time 5. Housekeeping and support service department are the key department to remain resilient	Interviewee try to elaborate that there were always some supporting departments which are very important. There are two main key department defined i.e. support services department and housekeeping department
1. Supply chain is the backbone of any industry 2. Improvement chance is always there 3. Good practices need to be adopted 4. Supply chaindead practices need to be re-evaluate 5. Must need to understand the difference between customer end and user end	Interviewee reveals the facts that organizational structure is very important for any organization to stay resilient. Good supply chain strategies are also important i.e. multiple suppliers, good feedback, try to identify the cracks and weakness of process, implementation of ERP system and at last good future prediction, which we called inventory forecasting in term of supply chain
1. We must have to face some personal issues when faced that kind of disruptions	Interviewee try to explain their personal issues when facing disruption
1. Every healthcare sector need good future forecasting	In these statements they are trying to explain their future planning tenure or the way healthcare sector prepared themselves for the future disruptions
1. Don't need to be afraid of natural disruptions 2. Always follow the safety precautions 3. Good organizational structure is very important for long time stability	In this part the keys lessons interviewees ty to explain us we must have to follow the precautions related to any disruption, Self-medication is good at certain level

demand situations (Polyviou et al. 2020). The findings also suggest that these teams need to have widespread support throughout the supply chain in order to succeed. The whole business as well as the entire supply chain needs to support the teams, according to Scholten et al. (2014). Teams lose influence and ability to make decisions without assistance from managers and workers (Chen et al. 2019).

Table 10.4 Initial theme, *source* Author

Initial theme	Theme cluster	Emergent theme
Interviewee try to explain the cost factor involving either shortage of items or prices boom dramatically. Which shows that if any disruption will occur we have to face these issues (i.e. shortage of important items either PPE's or machines, price fluctuation)	Shortage of Items	Cost effectiveness
	Price Fluctuation	
Interviewee try to elaborate that there were always some supporting departments which are very important. There are two main key department defined i.e. support services department and housekeeping department	Support departments	Collaboration
Interviewee reveals the facts that organizational structure is very important for any organization to stay resilient. Good supply chain strategies are also important i.e. multiple suppliers, good feedback, try to identify the cracks and weakness of process, implementation of ERP system and at last good future prediction which we called inventory forecasting in term of supply chain	Multiple suppliers	Flexible supply chain strategies
	ERP system	
	Inventory forecasting	
Interviewee try to explain their personal issues when facing disruption	Departmental conflicts	Conflict management
Future planning tenure or the way healthcare sector prepared themselves for the future disruptions	Preparation for future disruption	Future planning
We must have to follow the precautions related to any disruption, Self-medication is good at certain level	Precautions	Self-medication
	Safety measures	

10.4.3 Flexible Supply Chain Strategies

The results showed that flexible supply chain strategies are highly important for supply chain resilience. The findings are in line with Tang and Tomlin (2008) who suggested that inter-organizational initiatives should take flexibility into account and it has to be prevalent across the whole supply chain. Additionally, it gives businesses the flexibility to develop a wider range of solutions, which implies that they may be able to fend off a wider variety of disruptive occurrences. Jüttner and Maklan (2011) go on to say that flexibility may be a useful skill for developing answers to erratic demand and locating alternative supply sources to cut costs and meet irrationally escalating demand. This implies that adaptability may be utilised to combat both the outcomes' highly volatile supply and demand situations (Mubarik et al. 2021).

10.4.4 Conflict Management

Conflict management emerged as one of the enablers of supply chain resilience. During the time of COVID-19, supply chain disruption and conflicts occur in the workplace causing issues and distress in the working environment as well as the operations. The personal issues and conflict are the reasons of disruption in work which are caused by the pandemic. As stated by Hamid, support culture and conflict management are the major internal strategies that are important to enable supply chain resilience (Ali et al. 2023).

10.4.5 Future Planning

Future planning emerged as one of the themes for supply chain resilience. After COVID hit Pakistan, the major learning is that humanity cannot defeat the nature, if we have some natural disasters so we have to prepare ourselves for them and try to defend them. If we fail to do so we will must be bearing loss in future. This stresses upon the necessity of future planning in organization to avoid disruptions. This is in line with Scholten et al. (2014) who suggested that preparation and training regarding the whole supply chain enables the workforce to be more prepared to deal with supply chain disruptions (Scholten et al. 2014).

10.4.6 Self-medication

According to the responses, symptoms we should immediately contact to the doctor not rely ourselves on self-medication, we should keep ourselves self-medicated but at certain level when we feel now there is no advantage of self-medication you should immediately concern to the doctors because COVID is an epidemic and it will remain now for our life time, it will come from different names like wave one wave two but it will always be there so we should prepare ourselves for it.

10.5 Conclusion

Academics and practitioners aiming to focus on supply chain's performance in all circumstances frequently discuss the idea of supply chain resilience. Many previous studies on supply chain resilience have focused on defining the term or have only studied the social or technical facets of the topic (Hohenstein et al. 2015). A SEM-based approach towards the Utilization of Technology and its Relationship to the performance of private business education institutions. However, while being

sociotechnical systems (Wieland and Wallenburg 2013), supply chains are fundamentally a reflection of human behavior (Sweeney 2013; Miao et al. 2023). Academics and practitioners must comprehend the interaction between the human and technological components of supply chains in order to increase their resilience (Arif et al. 2023). The study found different enablers of supply chain resilience in healthcare sector. This includes cost effectiveness, collaboration, flexible supply chain strategies, conflict management, future planning and self-medication. The book chapter implies to focus on these factors in order to strengthen the supply chain network so that the organizations do not have to face risks and disruptions during crisis or pandemic period.

When taken as a whole, this book chapter offers more proof that, in order to build resilience within a supply chain and advance the knowledge of supply chain behavior, the social and technological elements of supply networks need to be investigated simultaneously. These pieces provide small but gradual advances in our comprehension of resilience and supply chain behavior. The book chapter also sheds light on support and conflict management as the key tools to avoid disruptions and uncertainties in supply chain.

Although the objective of the study was achieved, several limitations are important to address. Firstly, the study took a limited number of supply chain professionals working in healthcare sectors. This questions the generalizability of the study. For more generalized result, it is important to identify a specific factor and conduct a survey with as many hospitals as possible. Furthermore, the paper makes no mention of which supply chain resilience recovery techniques work. Even if this has nothing to do with the study's objectives, it is nonetheless interesting to know when assessing the applicability of the investigated supply chain resilience reactive techniques.

10.5.1 Insights and Implications Post-Covid Practice

The healthcare industry in Pakistan has been hit hard by the global disruption caused by the COVID-19 epidemic. Here are some takeaways and implications for bolstering supply chain resilience in the wake of the COVID pandemic:

- ***Digitalization***: The epidemic has stressed the need for more visibility and openness in the supply chain in real time. By using digital technology, Pakistani healthcare facilities may increase supply chain transparency, cut down on human error, and offer real-time information on inventory, demand, and availability. Better choices, optimized resources, and lessened supply chain interruptions can all result from this for healthcare firms (Khan et al. 2022a). Healthcare businesses in Pakistan can better plan for the inevitable disruptions to their operations by creating a risk management strategy. Part of this process is thinking ahead about what may go wrong and making preparations for it. Establishing alternative sources, storing essentials, and planning for swift action are all examples of risk management strategies. The epidemic highlighted the need to diversify supply

sources, especially in the healthcare industry. This has led to an increase in the importance of sourcing from several locations and producing goods domestically. By obtaining supplies from a variety of sources, Pakistani healthcare facilities will be less reliant on any one vendor or geographical area. This can lessen the duration of downtime caused by disturbances (Ishizaka et al. 2023).

- ***Boost Cooperation and Coordination***: Supply chain resilience relies on the cooperation and coordination of all parties involved. To better coordinate and align with their suppliers, regulators, and patients, healthcare companies in Pakistan should set up lines of communication and methods for collaboration. Data, expertise, and best practices may be shared, and coordinated reaction plans can be made. Healthcare has a huge influence on the environment, especially in terms of waste production, power usage, and GHG emissions. Thus, healthcare institutions in Pakistan may lessen their supply chain's carbon footprint by adopting sustainable practices like recycling and employing renewable energy. Supply chain resilience amid pandemic disruption in Pakistan's healthcare industry after COVID calls for a multi-stakeholder strategy that puts an emphasis on transparency, risk management, teamwork, and long-term viability. Healthcare firms in Pakistan can benefit from increased supply chain resilience, efficiency, and effectiveness by using these strategies (Jamil et al. 2023).

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Part IV
Conclusions and Future Research Directions

Chapter 11
Conclusions and a Way Forward

Hassan Qudrat-Ullah

Abstract This book examines how advanced technologies can help manage supply chains that face disruptions and enhance their resilience in the aftermath of Covid-19. The book provides a comprehensive and integrated overview and assessment of the latest developments and practices of supply chain management (SCM) and advanced technologies, as well as real-world examples and cases from different industries and settings. The book also offers useful suggestions and directions for SCM professionals, policymakers, and stakeholders on how to apply advanced technologies successfully and optimally in their supply chains. The book also identifies some gaps and challenges in the current literature and practice of SCM and advanced technologies and proposes a conceptual model for future research in this field. The book concludes with some final remarks and recommendations for improving supply chain performance and resilience through advanced technologies. The book is a valuable and insightful contribution to the field of SCM and aims to stimulate further research and discussion on the complex and fascinating phenomenon of SCM in relation to advanced technologies.

Keywords Advanced · Supply chains · Stakeholders · Conceptual model · Risk management · Sustainability of supply chain operations · Green supply chain management · Competitive advantage · Environmental issues · Adoption of advanced technologies · Aagile supply chain · Responsive supply chain

11.1 Introduction

This chapter summarizes the main findings and implications of this book, which examined how advanced technologies can help manage supply chains that face disruptions and enhance their resilience in the aftermath of Covid-19. The chapter also suggests some directions for future research on the relationship between

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advanced technologies and supply chain management (SCM). The chapter is organized as follows. Section 11.2 presents the key findings and implications for practice derived from the previous chapters of this book. Section 11.3 identifies some gaps and challenges in the current literature and practice of SCM and advanced technologies, and proposes a conceptual model for future research in this field. Section 11.4 concludes the chapter and the book with some final remarks and recommendations.

11.2 Key Findings and Implications for Practice

This book aimed to examine how advanced technologies can help manage supply chains that face disruptions and enhance their resilience in the aftermath of Covid-19. The book gave a thorough and integrated overview and assessment of the latest developments and practices of SCM and advanced technologies, as well as real-world examples and cases from different industries and settings. The book also provided useful suggestions and directions for SCM professionals, policymakers, and stakeholders on how to apply advanced technologies successfully and optimally in their supply chains.

The main findings and implications of this book for theory and practice are:

- Advanced technologies can enable more agile, responsive, and sustainable supply chain operations by providing better visibility, coordination, risk management, and contingency planning across the supply chain network.
- Advanced technologies can improve the quality, productivity, and sustainability of supply chain operations by reducing waste, energy consumption, emissions, and costs.
- Advanced technologies can enhance the creativity, innovation, and personalization of products and services by facilitating the collaboration of humans and machines.
- Advanced technologies can facilitate the adoption of green supply chain management practices that aim to reduce the environmental impacts of supply chain activities.
- Advanced technologies can create value and competitive advantage for supply chain organizations by aligning their supply chain strategy with their corporate strategy and customer needs and expectations.

11.3 Future Research Directions

Despite the exploration and successful demonstration of the role of advanced technologies in various aspects of supply chains in several domains, we, in this book, also acknowledge the limitations and challenges of using advanced technologies in SCM. Some of them are:

- The lack of standardization, interoperability, and compatibility of advanced technologies across different platforms, systems, and devices.
- The lack of skilled workforce, training, and education to use advanced technologies effectively and efficiently.
- The lack of trust, security, privacy, and ethics in the use of advanced technologies, especially those involving data collection, sharing, and analysis.
- The lack of regulation, governance, and compliance in the use of advanced technologies, especially those involving cross-border transactions, contracts, and disputes.
- The lack of awareness, readiness, and willingness to adopt advanced technologies among some supply chain partners, customers, and stakeholders.

To overcome the limitations and challenges, this book suggests some directions for future research. Some of them are:

- To develop frameworks, models, standards, and protocols for the integration, interoperability, and compatibility of advanced technologies across different platforms, systems, and devices.
- To conduct studies on the impact of advanced technologies on the skills, roles, responsibilities, and behaviors of supply chain workers and managers.
- To investigate the ethical, legal, social, and environmental issues related to the use of advanced technologies in SCM.
- To evaluate the effectiveness, efficiency, and return on investment of advanced technologies in SCM.
- To explore the adoption barriers and drivers of advanced technologies among different supply chain partners, customers, and stakeholders.

To facilitate the aforementioned future research, we present a conceptual model, in Fig. 11.1. This is a conceptual model of the relationship between advanced technologies (**AT**) and various aspects of supply chain management (SCM). It shows how different factors can influence the adoption and impact of advanced technologies in SCM.

The model shows that advanced technologies can have both opportunities and challenges in various aspects of SCM. For example:

- Opportunities and Positive effects: advanced technologies can improve the integration, interoperability, and compatibility of different supply chain processes, systems, and partners; enhance the skills, roles, responsibilities, and behaviors of supply chain workers and managers; address the ethical, legal, social, and environmental issues related to SCM; and increase the effectiveness, efficiency, and return on investment of SCM.
- Challenges: advanced technologies can also create challenges or risks for the integration, interoperability, and compatibility of different supply chain processes, systems, and partners; require new or different skills, roles, responsibilities, and behaviors of supply chain workers and managers; raise new or complex ethical, legal, social, and environmental issues related to SCM; and entail high costs or uncertainties for the adoption and implementation of SCM.

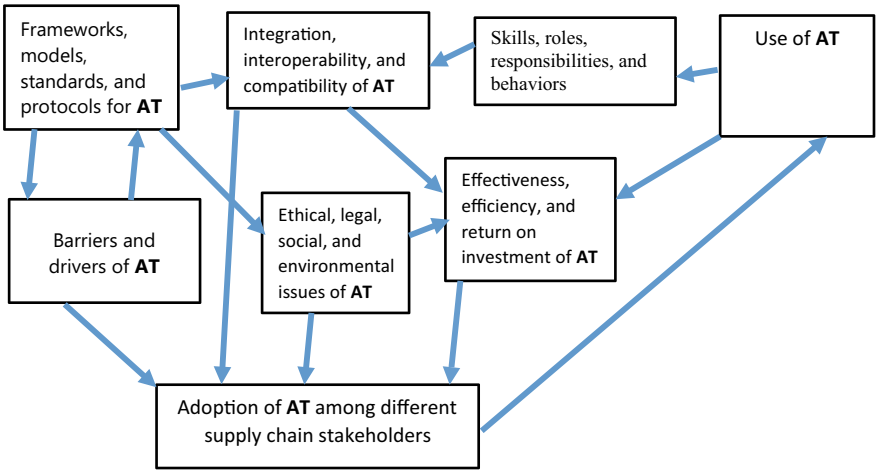

Fig. 11.1 A conceptual model for future research in SCM

The model also shows that many factors can influence the adoption of advanced technologies among different supply chain partners, customers, and stakeholders that future research can investigate empirically. Some of these factors are:

- *Barriers*: factors that hinder or prevent the adoption of advanced technologies in SCM, such as lack of awareness, knowledge, skills, trust, resources, infrastructure, etc.
- *Drivers*: factors that facilitate or encourage the adoption of advanced technologies in SCM, such as market demand, competitive advantage, innovation potential, cost reduction, performance improvement, etc.

The model suggests that there is no simple or direct relationship between advanced technologies and SCM. Rather, many factors can mediate or moderate the effects of advanced technologies on SCM. Some of these factors are:

- *Frameworks*: conceptual or theoretical structures that provide guidance or direction for the design or implementation of advanced technologies in SCM.
- *Models*: abstract or simplified representations that describe or explain the behavior or characteristics of advanced technologies in SCM.
- *Standards*: agreed-upon rules or criteria that define the quality or performance of advanced technologies in SCM.
- *Protocols*: established procedures or methods that regulate the communication or interaction of advanced technologies in SCM.

The model implies that there is *no one-size-fits-all solution* for improving SCM through advanced technologies. Rather, firms need to be aware of their own needs and preferences and adjust their use of advanced technologies accordingly. Some possible strategies are:

- *Evaluating*: assessing the benefits and costs of adopting or using advanced technologies in SCM for different purposes or contexts.
- *Selecting*: choosing the most appropriate or suitable advanced technologies for different SCM problems or opportunities.
- *Integrating*: combining or coordinating different advanced technologies to create synergies or complementarities for SCM.
- *Adapting*: modifying or customizing existing advanced technologies to fit specific SCM requirements or conditions.

In summary, this section has identified several gaps and directions for future research on the relationship between advanced technologies and SCM. Future research can explore how different factors, such as frameworks, models, standards, protocols, barriers, and drivers, can influence the adoption and impact of advanced technologies on various aspects of SCM, such as integration, interoperability, compatibility, skills, roles, responsibilities, behaviors, ethical, legal, social, environmental issues, effectiveness, efficiency, and return on investment. Future research can also employ different methods and approaches, such as surveys, experiments, case studies, simulations, etc., to collect and analyze data and generate insights or solutions for different SCM problems or opportunities. For empirical testing, this conceptual, structural equation modeling would be appropriate to account for mediating and moderating factors in this model. By doing so, future research can contribute to the advancement of knowledge and practice in the field of SCM.

11.4 Concluding Remarks

This book has explored how advanced technologies can help manage supply chains that face disruptions and enhance their resilience in the aftermath of Covid-19. The book has provided a comprehensive and integrated overview and assessment of the latest developments and practices of SCM and advanced technologies, as well as real-world examples and cases from different industries and settings. The book has also offered useful suggestions and directions for SCM professionals, policymakers, and stakeholders on how to apply advanced technologies successfully and optimally in their supply chains.

The book has shown that advanced technologies can enable more agile, responsive, and sustainable supply chain operations by providing better visibility, coordination, risk management, and contingency planning across the supply chain network. Advanced technologies can also improve the quality, productivity, and sustainability of supply chain operations by reducing waste, energy consumption, emissions, and costs. Moreover, advanced technologies can enhance the creativity, innovation, and personalization of products and services by facilitating the collaboration of humans and machines. Furthermore, advanced technologies can facilitate the adoption of green supply chain management practices that aim to reduce the environmental impacts of supply chain activities. Additionally, advanced technologies can

create value and competitive advantage for supply chain organizations by aligning their supply chain strategy with their corporate strategy and customer needs and expectations.

However, the book has also acknowledged the limitations and challenges of using advanced technologies in SCM. Some of these are the lack of standardization, interoperability, and compatibility of advanced technologies across different platforms, systems, and devices; the lack of skilled workforce, training, and education to use advanced technologies effectively and efficiently; the lack of trust, security, privacy, and ethics in the use of advanced technologies; the lack of regulation, governance, and compliance in the use of advanced technologies; and the lack of awareness, readiness, and willingness to adopt advanced technologies among some supply chain partners, customers, and stakeholders.

Therefore, the book has suggested some directions for future research on the relationship between advanced technologies and SCM. Future research can explore how different factors, such as frameworks, models, standards, protocols, barriers, and drivers, can influence the adoption and impact of advanced technologies on various aspects of SCM. Future research can also employ different methods and approaches to collect and analyze data and generate insights or solutions for different SCM problems or opportunities.

We hope that this book has offered a valuable and insightful contribution to the field of SCM. We also hope that this book has stimulated further research and discussion on the complex and fascinating phenomenon of SCM in relation to advanced technologies. We also hope that this book has provided some practical guidance and recommendations for SCM practitioners, policymakers, and stakeholders on how to improve their supply chain performance and resilience through advanced technologies.

We would like to thank all the authors who contributed to this book with their expertise and experience. We would also like to thank all the reviewers who provided constructive feedback and suggestions for improving the quality of this book. Finally, we would like to thank all the readers who have shown interest in this book. We hope that you have enjoyed reading this book as much as we have enjoyed writing it. You, the reader, be the judge ☺. Will appreciate your comments at hassanq@yorku.ca.

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