National College of Ireland

Project Submission Sheet

Student Name:	Mark Atul Massey		
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Signature: Mark Atul Massey

Date: 15th August 2025

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AI Acknowledgement Supplement

Dissertation

Overcoming Disruptions in Global Supply Chain: The Role Of Digital Transformation in Post-Pandemic

Your Name/Student Number	Course	Date
Mark Atul Massey	MSc in International Business	15th August 2025

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Additional Evidence:

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Additional Evidence:

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Submission of Thesis and Dissertation

National College of Ireland
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(Thesis/Author Declaration Form)

Name: Mark Massey

Student Number: 23293284

Degree for which thesis is submitted: MSc in International Business

Title of Thesis: Overcoming Disruptions in Global Supply Chain: The Role Of Digital Transformation in Post-Pandemic

Date: 15th August 2025 _____

Material submitted for award

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OVERCOMING DISRUPTIONS IN GLOBAL SUPPLY CHAIN: THE ROLE OF DIGITAL TRANSFORMATION IN POST-PANDEMIC

MSc Research Project

M. Sc International Business

Mark Massey

Student ID: 23293284

School of Business

National College of Ireland

Supervisor: James O'Connor

Abstract

The introduction chapter provides an overview of the research problem including the evidence of the pandemic revealing weaknesses in traditional supply chains and sets the study's aim, objectives, and theoretical framework.

The literature review has looked at the current body of knowledge on global supply chain shocks, especially in times of COVID-19 and how digital transformation helps attain resilience, efficiency, and sustainability. It was able to determine important barriers, facilitators, and theoretical frameworks, and it forms a solid background to comprehend digitally induced supply chain modernisation in the post-pandemic period.

The methodology chapter outlines the ‘mixed-methods methodology’ that was applied to study digital transformation in global supply chains. It follows an ‘interpretivism philosophy’, which combines ‘qualitative semi-structured interviews’ with ‘quantitative closed-ended questionnaires. The research design adheres to ‘Saunders’ Research Onion’ and was developed ‘inductively and deductively’. The data were analysed using ‘thematic analysis’ using ‘NVivo and descriptive statistics. In order to preserve ‘credibility and reliability, ethical concerns, sampling methods, and validity’ measures were pursued for compliance with the research aims.

Results and discussion Chapter outlined results of the interviews with supply chain professionals, impact of COVID-19 and effectiveness of digital tools in enhancing their visibility, efficiency and sustainability using interview (qualitative) and survey (quantitative) research processes. It examined blockers and drivers of digital adoption, providing evidence-based opinions that encouraged the technology-driven approach of supply chain strategies and made it easier to make decisions.

The conclusion chapter highlighted the most important research results, stressing the importance of digital transformation in successfully facilitating the recovery in the face of global chain of supply disruption in the wake of the pandemic. It gave practical suggestions to organisations, pointed out the significance of technology-enabled resilience, and provided the scope of future research to enhance supply chain security, effective operations, and sustainability in a changing business environment.

Acknowledgement

I would like to say thank you to my supervisor who has provided me with invaluable guidance and positive feedback and at all times, the necessary support during my dissertation. I owe a great debt of gratitude to supply chain professionals and industry experts who kindly gave me their time and knowledge and helped me make this research richly supported. My gratitude also goes to my family and friends who have supported me and understood me all through this process. Lastly, I thank my academic institution because it has provided the resources and platform through which this work was completed. Their efforts have been invaluable in ensuring that this dissertation has been successful.

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Chapter 1: Introduction

1.1 Research Background

Complex networks of closely related systems are an integral part of global supply chains, which represent the central pillar of the global economy through which goods, services, information, and capital flow efficiently across borders (Zhang, 2023). By historical design, global supply chains are in most cases, built around the lean, just-in-time and low-cost global sourcing supply chain operations. Global supply chains are geared by cost effectiveness, speed and proximity to markets. The COVID-19 pandemic showed massive weaknesses of traditional supply chain behaviour (Schleper et al., 2021). Borders were shut, factories were shut, product categories gained or lost value in weeks and as production lines stopped and consumers' shopping behaviour changed overnight, companies across the world struggled to keep their supply lines open, resulting in tears and shortages.

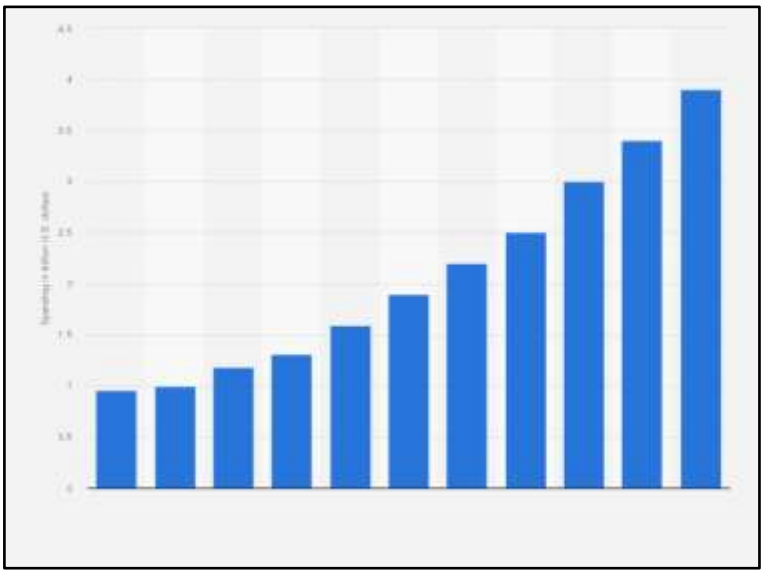

Figure 1: Global Digital Transformation

(Source: Statista, 2024)

The pandemic was a pretty strong wake-up call in this regard, demonstrating how woefully unprepared global supply chains are when it comes to dealing with unexpected shocks. Lockdowns, transport freezes, labour shortages, and unpredictable demand shocks that prompted

factory shutdowns have led to production stoppages, which have caused entire industries to grind to a halt. 80% of businesses cited supply chain issues as "worthy" during the pandemic (Sodhi *et al*., 2021). If nothing else, it exposes the fragility of current systems. Companies relying on single-source suppliers and thinning inventory were beset when supply chains went haywire.

The requirements for resilient and flexible supply chains became apparent. For companies, the idea emerged that merely surviving disruption was not enough instead, companies needed to become prepared for disruption and know how to respond more effectively (Roblek *et al*., 2021). Culturally, that created an environment where digitalisation of supply chain management was encouraged. How will Artificial Intelligence (AI), Blockchain and Internet of Things (IoT) play a role in their rebuilding, and how will the technologies help to better optimise and future-proof supply chains?

Predictive analytics is the name, AI is one of the drivers and it serves as the easiest way an organisation can respond faster and with less manual intervention (Bari and Ara, 2025). Blockchain offers audit evidence and non-repudiable transaction information and enhances trust and visibility between supply chain members. At the same time, the IoT allows for visibility in real-time of inventory, transport, hosts, and storage conditions, which enhances this visibility and responsiveness of the organisation.

The pandemic accelerated e-commerce, which needs faster, more accurate and customer-responsive supply chain operations. In this regard, digitalisation has deep implications for business as an indication of a profound change in the way they operate, plan, execute, and respond to events. Companies that had digitalised their supply chains enjoyed several advantages in -quicker recovery, sustaining position in market as well as in optimal market share's competitive advantage (Jafari *et al*., 2022).

The current issues and the post-pandemic world Essentially, it can be observed that Joint Webinar Are you ready to "ReStart" Supply Chain? This study is an investigation into how organisations can exploit digital transformation opportunities to identify and grow resilience and efficiency opportunities on that global supply chain which exists in a volatile world.

1.2 Aim and Objectives

Aim:

The current research will study how digital transformation can improve the resilience and efficiency of global supply chains in a post-pandemic world.

Objectives:

- To determine the impact of 'COVID-19' on global supply chain operations.
- To evaluate how digital transformation can improve operational efficiency, visibility, and sustainability.
- To recognise the main barriers and enablers to implementing digital transformation in supply chains.
- To provide recommendations for organisations with supply chains, who wish to modernise and bolster security and efficiency through digital tools.

1.3 Research Question

What are the ways that digital transformation can improve the resilience and efficiency of global supply chains in the post-pandemic era?

1.4 Research Problem

The 'COVID-19 pandemic' exposed vulnerabilities in global supply chain systems, including visibility and transparency, responsiveness, and dependence on suppliers. It was those that were cost-optimised that suffered most from such spare-line setbacks, logistical limitations or supply/demand swings that led to abrupt closures (Choksy *et al*., 2022). The pandemic has laid bare one big challenge: Global supply chains were not built for disruption.

Organisations cannot afford to wait, yet they can't get "digitally stuff done." Digital solutions offer clear benefits, such as better predictive maintenance, improved tracking as well as secure transactions, but digital technologies ('AI, IoT, Blockchain') are not being employed either due to organisational inertia, lack of digital capabilities or lack of alignment with the strategy. In

addition, companies are uncertain how they can capitalise on these technologies, in tandem, to increase smartness or efficiencies at the operational level (Bisht *et al*., 2021). This research challenge centres on the strategic and operational challenges facing the digital transformation of supply chains; finding concrete examples and advancing our theoretical understanding of the issue to create a gap and space between the aspiration of digital technology and doing, and the chance to establish a resilient capability in agile supply chains which are future-proof.

1.5 Research Rationale

The motivation for this work resides in the global need to re-imagine and digitalise supply chains, with the current disruption being at an unprecedented scale (Bennett and McWhorter, 2021). The pandemic has not occurred in isolation as a single event; rather, it illustrates the kinds of challenges supply chains will increasingly have to tackle in response to an array of global crises of health, geopolitics, and the environment. Enterprises need to shift from defensive policies to proactive, technologically enabled approaches.

Digital transformation can bring radically improved predictability, traceability, and flexibility to supply chain systems. As the majority of what is available has treated different technologies in isolation as opposed to considering their aggregate value for resilience as well as for efficiencies (Ghobakhloo *et al.*, 2023). Moreover, there is scarce qualitative data on how such digital tools were experienced by industry practitioners during the crisis. The present study will start to address this lack in the literature by investigating how supply chain managers concoct the combination of technologies they used during the pandemic in the absence of non-digital systems and what challenges still lie ahead. Such study could offer a promising first step to provide an applicable roadmap for supply chain manager, as well as contribute to the relevant scholarly discussions about digital innovation and operational resilience in their firms. As a result, the study will contribute to more adaptive, sustainable and technology-enabled supply chain patterns amid a global system of greater unpredictability.

1.6 Research Significance

Academically, it contributes to the literature on digital transformation from a strategy perspective in the supply chain management domain, a key growth area ‘post-COVID-19’, and it utilises

both qualitative reality and theoretical perspective to offer a rich picture of innovation in the context of the supply chain adoption.

Based on some viewpoints, the research provides practical implications for businesses that if they intent to adopt or use digital technologies in their supply chain operation benefit from the work, as key success factors, challenges and enablers for supply chain planning to take that decision into consideration when they plan their strategies (Stroumpoulis and Kopanaki, 2022). More generally, the study contributes to the development of globally resilient and sustainable trading systems, which are critical for mitigating the economic and social impacts of large-scale global disturbances in the future. Results offer insights for both industry policy and governmental initiatives on digital infrastructure and supply chain innovation.

1.7 Research Limitations

As the study is qualitative which can privilege depth over generalizability? The consequences of this deduction will only be valid for the subset of supply chain practitioners from whom the lessons are learned and will not be portable across industries and across geographies. Second, only the seeding of three digital technologies (AI, Blockchain and 'IoT') is conducted. Other technologies, such as robotics, cloud technologies, as well as cybersecurity technologies, though suitable, are outside the focus at the moment.

Third, due to constraints of time and financial resources, the study will be restricted in terms of a number of interviews and survey responses, which in turn may limit the range of the perspectives. Lastly, the study is a study of a 'post-COVID-19' recovery, which as a topical research area, is timely, but in the absence of other contemporary risks, such as new conflicts or climate-induced disasters, this can be seen as somewhat limited. That said, the research will set the stage for future work that may be stronger or have a broader scope.

1.8 Research Structure

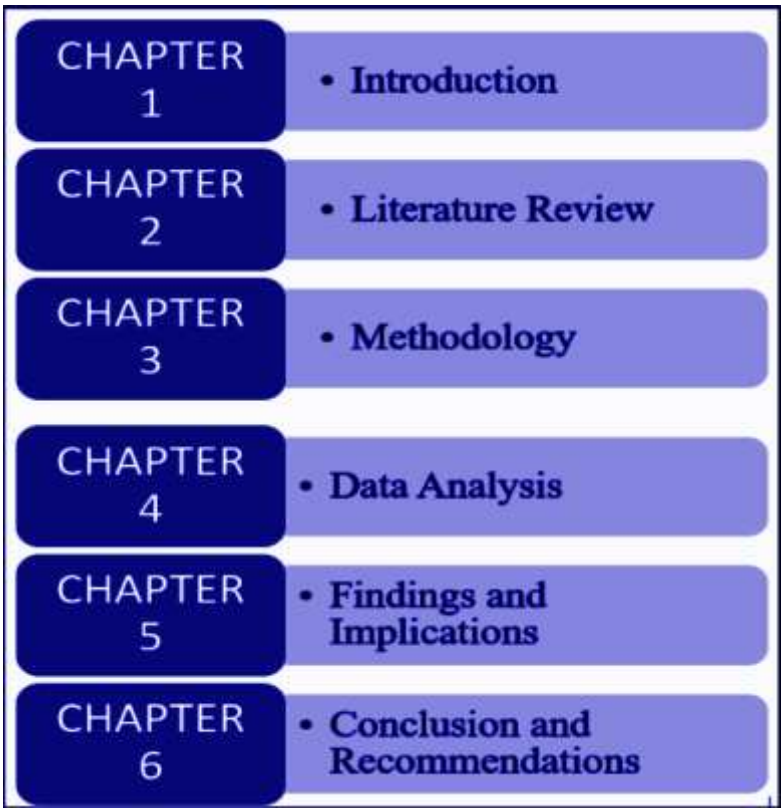

Figure 2: Research Structure

(Source: Self-Created)

1.9 Summary

This introduction has emphasised the imperative of rethinking the world supply chains post-pandemic, providing context for digitalisation as a means of achieving resilience and efficiency. Chapter 1 was devoted to the presentation of problem and explanation, justification and rationale of the study and the methodology to be used and to listing a research statement and research questions. The chapter concluded with a discussion of the dissertation format and limitations.

Chapter 2: Literature Review

2.1 Introduction

The COVID-19 pandemic highlighted the fragility of delivery chains across the world and has led groups to rethink and redesign their delivery chains globally. The literature assessment affords an outline of the approaches virtual transformation has emerged as a strategic repositioning manner to construct resilience, performance, and sustainability within deliver chains. The literature assessment is prepared in 3 sections constructed upon a few empirical studies from quite a number of industries and countries, a proof of the theoretical frameworks underpinning the study, and a conceptual framework. Research gaps are highlighted afterwards, then understanding is synthesised with the position of technology, together with AI, IoT, and blockchain in shaping the post-pandemic delivery chain.

2.2 Empirical study

2.2.1 Supply chain operations across different industries and countries before the pandemic

Pharmaceutical industry

USA

According to Odumbo *et al.* (2024), the pharmaceutical supply chain has catered to the function of efficiency rather than resilience, and the traditional model attributes have mainly focused on the lean, centralised manufacturing and just-in-time process to reduce their operational costs. In the USA, one of the most recognised inefficiencies was the structural implications and the equity gaps that have impacted the rural communities. Despite technological evolution, the pharmaceutical supply system has experienced structural fragmentation that, as a result, undermines the equitable distribution across the pharmaceutical companies in the US. The opioid distribution crisis serves as an extraordinary example that implicates the measures of distribution only within the high-demand regions, resulting in severe public health consequences. Moreover, the mass production techniques, standardisation of drug production by the FDA have allowed for the establishment of the centralised pharmaceutical supply chains. For example, Pfizer and Biotech have already begun their work much earlier than the approach towards the facilitation of

the supply chain for the vaccine measures. Prior to the pandemic, the company had operated through lean practices in the operation, while the high rise on demand for vaccines has allowed the company to shift towards digital aspects to develop effective functions (Bown and Bollyky, 2022).

China

On the other hand, Kuo *et al*. (2021) opined that about 40% of the medications in Taiwan rely on the APIs that are produced in China, which holds the chance to disrupt the seamless supply chain practices in case of the continuation of COVID-19. Misallocations of medications in its internal measures, fragmented distribution, and additionally, the over-reliance on the APIs have also been great concerns for the pharmaceutical industry in China.

As opined by Wells *et al.* (2024), the weak strategic implication in Pfizer's operation is an excellent example that highlights the failure in the supply chain measures. The reason is due to the shortage of the API for the explosion, as the factors have impacted Pfizer's measures to supply the antibiotics, disrupting the process. This indicates a lack of transparency, regulatory measures within the region that impact the production of antibiotics.

Japan

According to Bas *et al*. (2023), Japan has employed skilled employees or physiotherapists to govern the applications of the supply chain related to hospitals. Moreover, the healthcare supply chain has been complex and is difficult to manage due to the "medical and pharmacological speciality issues". Moreover, the industry has to deliver notable changes within its operations with the advent of pandemics.

Automotive

USA

Klug *et al.* (2022), the address on the Just-In-Sequence focuses on the two-tier supply chain that allows for delivering parts to the assembly line in the exact process, yet sequentially. This, as a result, allows for minimising the inventory, reducing waste and streamlining the assembly process. It is one of the notable processes escalated in the USA and allows for ensuring measures

to facilitate seamless processes in the supply chain. Milewski (2022) has stated that the cross-docking centres, stocking facilities, lean management application and Just-In-Time approaches have been facilitated over the operations of Toyota. Therefore, the full application of the JIT Concept within the operations of Toyota has allowed them to regulate efficiency in the process.

China

As opined by Huang *et al.* (2023), the supply chain management procedures in China have been affected by the rise of geopolitical issues despite its strong measures in regulating the behaviour facilitated over the supply chain operations. The maintenance of the resilient features and the identification of the vulnerabilities have always been a sensitive concern in the supply chain operations within China.

Japan

Maeno *et al.* (2022) have stated that supply chain restructuring has been a recognisable work facilitated by Toyota, and it has also embraced the Carbon Disclosure Project to ensure sustainable applications in their process. The assurances towards environmental protection have indicated that the automotive industry in Japan regulates responsible and centralised practices in their supply chain process.

Retail

USA

According to Varriale *et al*. (2021), the supply chain facilities in the USA have always been highlighted due to their strong initiatives in technological implication, such as RFID for enhancing the supply chain operations. This allows for constant monitoring of the products and allows for improving the issues, which, as a result, allows for accelerating the process of shipment and the procurement phase.

China

Chen *et al.* (2024) have stated that Alibaba has already implemented the use of e-commerce resources for promoting their logistics operations and also facilitated the RFID technology to

develop a seamless performance within their cross-border logistics. The utilisation of blockchain within the SC has allowed the company to ensure efficiency and transparent approaches.

Japan

On the other hand, Schroeder and Lodemann (2021), the natural disasters in Japan have resulted in disrupting numerous networks and negatively within business operations. These facilitate the development of the ML and the SCRM to reduce their risks by levelling up their strategies in terms of technologies, systems and processes.

2.2.2 post-pandemic transformation within the supply chain practices in different industries and countries.

Pharmaceutical

Wong *et al.* (2023) stated that the sudden demand for medical applications after the pandemic has resulted in the Pharma 4.0, which allowed the implication of AI, Iot in the industry has been able to deliver flexible measures in the production process. This has reduced the delivery measures and affected the productivity process, and the connectivity has developed an effective response towards the supply shortage.

As per the views of Ma *et al.* (2022), traceability in the supply chain measured through the application of BCT has been a significant lesson derived from the pandemic. Continuous monitoring, regulation, and tracking measures are the key attributes which has been developed due to the possibility of traceability.

On the contrary, Trabucco and De Giovanni (2021) have opined that the adoption of the lean coordination mechanisms and strategies has allowed the companies in China to ensure effective allocation of the resources, focusing on the external environment and developing resilience in the business operations in terms of sustainability and efficiency.

According to Ogbuagu et al. (2023), the facilities of the GMP and the follow-up on the guidelines implemented by the ICH have allowed Japan and other countries to focus on the technical aspects effectively for resilience supply chain applications. It maintains regulatory

adherence, avoids contamination, maintains temperature and additionally, guarantees product integrity throughout the line of manufacturing process.

Liu *et al.* (2025) have stated that Chinese pharmaceutical companies have focused on the more strict regulatory measures, partnership facilities for their development of medical devices and additionally, their initiative for the investment features in local production, R&D after the post-pandemic era resulted in the supply chain resilience.

Automotive

Based on the opinions of Nkuna *et al* (2023), it can be stated that the use of JIT through the TPS has enhanced in the recent times mainly after the pandemic to address on the inefficiencies within the production and delivery facilities. The acknowledgement of the MRP and the MRP 2 planning in the operations of Toyota has allowed for maintaining the stock decrease process and ensuring sustainable measures in the operation of the company.

On the other hand, Lin *et al.* (2021) stated that the supplier's strategy leads to delivering effective functionalities and developing a more resilient process in response to diversification of the suppliers. This, as a result, allows organisations to get immediate help from other suppliers in times of need to facilitate the seamless process.

Siota and Prats (2021) stated that Toyota Motor Corporation has facilitated collaboration with start-ups on better predictive maintenance, data analytics and supplier-risk scoring systems. As a result, has allowed for the reduction of operations due to enhanced logistics automation and smart warehouse systems.

According to Monsone (2021), the lean supply chain measures and the implementation of better production cycle measures in response to the industry standards have allowed for the implementation of a digital twin to optimise the supply chain processes. Moreover, it has also allowed for testing of the new production process for the development of the virtual phase of the real processes.

Retail

As opined by Anica-Popa *et al.* (2023), the RPA approaches and different digital efficiencies have been integrated into Alibaba to enhance their resilience in the supply chain measures. The implementation of AI-driven demand forecasting, driverless warehouses, and smart tracking products through blockchain facilities has been effective in bringing seamless operations.

On the other hand, Qi (2022) has stated that the measures of AliExpress have facilitated new measures within their supply chain operation to control the delays and cross-border limitations. This has been effective through the implementation of AI mechanisms in their global transportation strategy and investments in strategic collaboration approaches to establish seamless SCM procedures.

Rahman (2024) stated that the pandemic has transformed the facilities in Alibaba, and the implication of predictive analytics in the Japanese market has allowed the company to predict the preferences of the customers and the market. This, as a result, has allowed organisations to reduce the overstressing measures and also ensure sustainable approaches.

2.2.3 Prospects of digital technologies within the supply chain measures across the companies during the pre- and post-pandemic era.

According to Beninger *et al.* (2022), the measures of the Pharmacovigilance Strategy are required and are considered the cornerstone of the pharmaceutical industry. Before the pandemic, the initiatives had not been addressed much and therefore, without clear guidance for reporting and acknowledging the events, led to shortages, recalls hampering the seamless process of the supply chain. For example, the implementation of digital technologies in Pfizer, such as Iot for detailed monitoring functionalities, CT to address the traceability, has been effective in reducing inefficiencies by the identification of the risks and developing effective risk management initiatives to ensure seamless SCM (Pilati *et al.*, 2021).

On the other hand, Salim and Abdillah (2022) stated that the ERP solutions and the JIT facilities were recognisable within the automotive industry during the pre-pandemic era that has ensured effective function yet developed constraints in offering measures to the fragmented SC operations. Moreover, the investments in the application of the digital twin prospects allowed for

monitoring the facilities regarding the SC operations to develop effective strategies to facilitate seamless operations to ensure success in the upcoming times.

On the other hand, Zhang (2024) stated that the Cainiao network application by Alibaba within the logistic operations was inherited before the pandemic and drives the digitalisation of logistics and supply chain measures. Moreover, the incorporation of big data analytics in business functionalities has allowed for demand forecasting, which, as a result, allows organisations to predict the demands and the network has allowed for the optimisation of the delivery routes to ensure the delivery measures.

Lu *et al*. (2021) stated that the implementation of Cainiao, along with the combination of cloud computing, ML algorithms set up by the company, enhances the last-mile operations to develop a resilient SCM. In addition to that, the application of blockchain technology to ensure of transparency in business features has been a promising opportunity for organisations to develop customer trust regarding ethical SC measures.

2.2.4 The impact of the role of Digital Transformation in relation to post Pandemic (after Covid 19) in supply chain.

According to Frederico (2021), the COVID-19 pandemic significantly and negatively impacted global supply chains, revealing unquestionable weaknesses in every sector, while emphasising that all sectors require substantial change. Firms implemented digital transformations by incorporating artificial intelligence (AI), blockchain, and the Internet of Things (IoT) into their supply chains in order to meet the challenges brought forth by the crisis, so they could have a company at all. The current section will examine three industries and three companies: pharmaceuticals (Pfizer, USA), retail (Alibaba, China), and automotive (Toyota, Japan) to show how companies implemented digital transformation to improve resilience, enhance efficiency, and increase agility related to the supply chain in response to the pandemic.

On the other side, Kouam (2025), taking these principles into account, Pfizer, one of the largest global biopharmaceutical companies in the U.S., exemplifies what can occur with digital transformation in the pharmaceutical space. Before COVID-19, in the United States, pharmaceutical supply chains were run with just-in-time inventories, globally sourced, with

reactive forecasting (Balkhi *et al*., 2022). It was business as usual. With the pandemic, demand quickly grew, and all aspects of logistics were completely disrupted. Pfizer soon realised that the unpredictability of the pandemic necessitated a complete rethink of the supply chain, so that vaccines and treatments could be delivered quickly and reliably to hundreds of millions of people.

Similarly, as per the study by Aljohani (2023) to face this big challenge, having assessed the risks, Pfizer set out to apply AI-powered predictive analytics to manipulate calls for forecasting, are expecting to deliver a shortfall and assess present confined assets dynamically. They expected wherein the most important person's desires could be fulfilled at one time and directed to deliver strains to fulfill the call (Dura *et al*., 2025). They used this making plans and forecasting method and have been experiencing ways much fewer inventory outs, supplied surprisingly equitable distribution of their product, whilst the worldwide call for changed into swiftly changing.

Silkoset and Nygaard (2025) states that Pfizer had moreover performed blockchain era to manual transparency and integrity in its vaccine supply chain. As counterfeit prescribed drugs are developing in importance in some unspecified time in the future of catastrophe situations, blockchain furnished Pfizer verifiable records, with tamper-proof documentation of every element of vaccine production, distribution, and delivery. These superior stages are given as proper with governments, health-care providers, and patients. Digital dashboards, moreover, synthesised statistics from suppliers, manufacturers, and logistics partners, providing end-to-end visibility of the supply chain. With this era in place, Pfizer changed into leveraging an adaptive, trusted network that changed into extra robust than their traditional reactive systems to take on the fantastic and complex desires of the pandemic, and beyond.

As noted by Tagde *et al*. (2021), Alibaba responded by rapidly scaling its AI logistics platform Cainiao, which incorporated predictive analytics, cloud computing, and smart warehousing, to manage the crisis effectively. In retail, Alibaba, the largest e-commerce company in China, exemplified how digital transformation allowed it to fulfil rapidly escalating consumer demand while being able to adapt to continuously evolving conditions amid the COVID-19 pandemic. Before COVID-19, Alibaba had a complex e-commerce ecosystem and emerging logistics

network. In the case of Alibaba, AI models were able to help predict changes in consumer behaviour, thereby informing delivery route optimisation as well as how to allocate inventory across warehouses to mitigate delays stock stockouts.

Furthermore, Scott *et al*. (2025) state that Alibaba drastically applied IoT technology through nearly all components of its logistics operation. Using IoT sensors, stock ranges, and warehouse conditions, cars operated, etc., have been constantly monitored to permit for real-time adjustments to distribution plans, and have brought the advantage of ensuring higher popularity for perishable products. One of the most important ameliorations at some point of the pandemic became Alibaba`s acceleration of deploying self-sufficient shipping robots and drones. Robots and drones have now become an effective device for mitigating hard work shortages because of lockdowns, however additionally decreased and removed human contact, which has become a concern for delivery chain protocols for transmission risk reduction (Kandhare *et al.*, 2025). Likewise, the usage of blockchain furnished a degree of consideration and authenticity in recording transactions. In the car industry, Toyota, the biggest carmaker in Japan, offers an instance of the way corporations leveraged virtual transformation to mitigate the dangers related to their preceding lean, just-in-time manufacturing model. Before the COVID-19 pandemic, Toyota`s delivery chain changed its idea to be near best given the working understanding and its near-0 reliance on stock. However, this technique left Toyota prone to foremost disruptions, in particular, while felony mandates to close down provider networks and the breakdown of worldwide logistics occurred.

As per the study by Goswami *et al.* (2024) Toyota employed AI-enabled analytics to track supplier performance, predict supplier disruptions, and identify alternative suppliers early on. Through data on transportation delays, geopolitical risk, and suppliers' financial stability, AI-derived models provided Toyota with actionable insights that allowed them to diversify suppliers and create strategic buffers for key components. This predictive capability resulted in Toyota being able to restore operational stability faster than many of its competitors. Furthermore, Internet of Things (IoT) sensors have been systematically hooked up all through their factories, distribution centers, and motors to determine and track the location and status of each piece of equipment, deliveries, and inventories (Chen and Biswas, 2021). As a result, managers have been capable of dynamically manipulating bottlenecks, system failures, or transportation problems

with real-time data, growing their agile talents and visibility. The case studies of Pfizer, Alibaba, and Toyota showcase varied ways digital transformation allowed organisations to address vulnerabilities brought to light during the COVID-19 pandemic. Pfizer embraced AI and blockchain sources to predict demand, facilitate distribution, and create transparency all vital elements of success in an industry that prioritizes rapid, accurate, and transparent responses. Alibaba utilized available AI logistics platform technologies, IoT enablement visibility, and autonomous delivery systems, to meet unprecedented demand with logistical cordiality; and simultaneously served to promote and protect public health.

Company & Industry	Pre-COVID-19	Post-COVID-19
Pfizer (Pharma, USA)	Lean inventory, limited real-time visibility, reactive demand planning.	AI-enabled forecasting, blockchain for transparency, proactive and adaptive supply chain.
Alibaba (Retail, China)	E-commerce with growing logistics, moderate automation, and human-dependent delivery.	AI & IoT-enhanced logistics, drones & robots for delivery, blockchain for trust.
Toyota (Auto, Japan)	Just-in-time with minimal buffers, rigid supplier networks, and limited risk anticipation.	AI-driven risk prediction, IoT-enabled monitoring, cloud-based collaboration, and greater flexibility.

Table 1: Comparison of Pre-Pandemic and Post-Pandemic Impact

(Source: Self-Created)

The desk also emphasizes how country-specific contexts influenced every company's digital transformation journey. For example, in the United States, Pfizer benefited from the countries more competitive technological environment and stronger focus on innovation, which allowed for the rapid deployment of AI and blockchain in healthcare. Meanwhile, in China, Alibaba could apply the government's support for digital infrastructure and its pre-existing investments to champion intelligent logistics and independent technology nationally.

2.3 Theoretical Framework

In order to understand how digital transformation affects supply chain resilience and efficiency after the COVID-19 pandemic, we must ground the analysis in sound theoretical perspectives. The ‘Resource-Based View (RBV)’, ‘Dynamic Capabilities Theory’, and ‘Supply Chain Resilience (SCR) Theory’ are three dominant theories that facilitate an analysis of how.

Resource-Based View (RBV)

The resource-based view (RBV) proposes that long-term competitive advantage is reached by firm set of resources that are valuable, rare, inimitable, and non-substitution (VRIN)-centric. Unique to RBV is the notion that a company`s internal resources and capabilities are key to the firm's ability to compete, unlike more conventional economic models, which focus strictly on external market circumstances (Wartini *et al*, 2024). In this post-pandemic era of supply chain, digital technologies, including those of AI, IoT, and blockchain are strategic assets to capitalise on the performance and resilience.

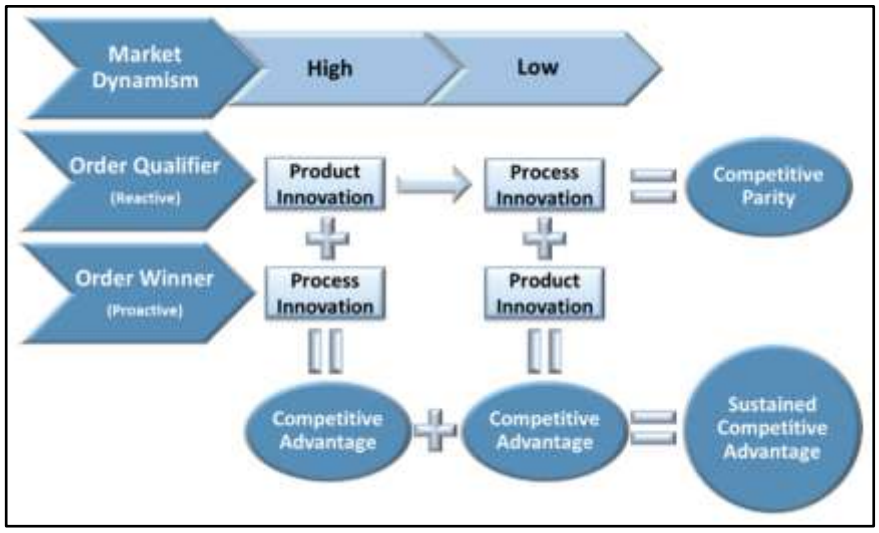

Figure 3: RBV Theory

(Source: Cho and Linderman, 2020)

Companies that fully leverage AI, IoT, and blockchain are able to redefine the value proposition through bespoke, distinctive capabilities such as real-time insight into the supply chain, predictive analytics, and secure, audited transactions. For example, AI-based forecasting systems have increased the capacity of firms to respond to demand variability, while the honesty between buyers and suppliers is facilitated through the use of blockchain-supported transparent records (Beamish and Chakravarty, 2021). These capabilities satisfy the VRIN requirement because they are both technologically better (valuable), not commonly applied (rare), hard to reproduce (inimitable), and generate specific supply chain advantages (non-substitutable).

Dynamic Capabilities Theory

'Dynamic Capabilities Theory' expands in this view by explaining how companies respond and rearrange their sources to satisfy fast adjustments of their environment (Chari *et al*., 2022). The concept considers dynamic competencies because of the potential to understand possibilities and threats, capture possibilities through funding and aid reconfiguration, and rework organizational procedures to stay competitive. During the COVID-19 pandemic, delivery chains confronted extraordinary disruption, requiring companies to increase dynamic competencies to live to tell the tale and prosper. Digital technology performed a crucial function in setting up those

competencies. AI and predictive analytics proved beneficial in assisting companies to make adjustments in call for or deliver conditions.

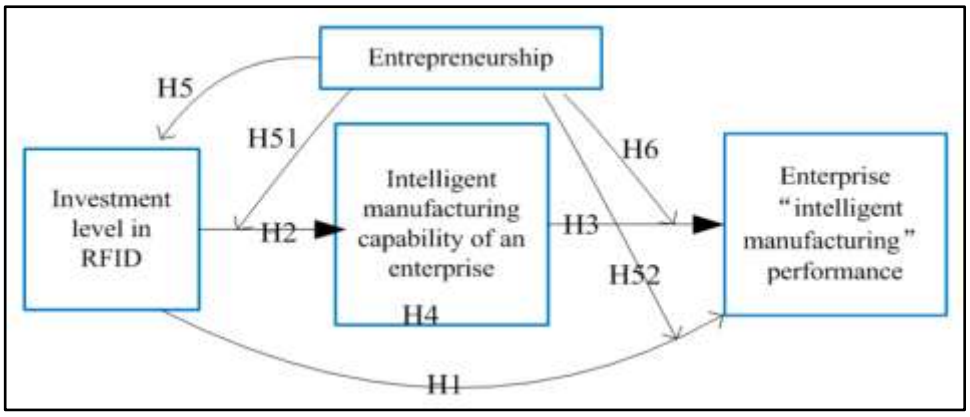

Figure 4: RBV Theory

(Source: Wang and Liu, 2023)

IoT sensors and related gadgets allowed companies to capture possibilities through enhancing manufacturing or transport in real time. Lastly, blockchain and cloud structures helped companies rework current procedures into extra agile, transparent, and collaborative strategies for doing business (Xu and Hou, 2024). 'Dynamic Capabilities Theory' underscores the reality that simply owning virtual equipment is insufficient; companies have to constantly learn, integrate, and reconfigure their technology to conform to evolving challenges. For instance, corporations that unexpectedly shifted to omnichannel retailing, leveraged virtual twins for digital manufacturing, or brought self-sustaining logistics structures verified the dynamic competencies essential to outperform the competition in a risky post-pandemic environment.

Supply Chain Resilience (SCR) Theory

The 'Supply Chain Resilience (SCR) Theory' affords a greater precise lens that is centred on the delivery chain. Supply chain resilience is because of the potential of a delivery chain to put together, respond to, and recover from operational disruptions whilst ensuring continuity of operations and performance (Hossain *et al*., 2024). SCR concept locations make a specialty in the four traits that help resilient delivery chains: 'Agility, flexibility, redundancy, and visibility'.

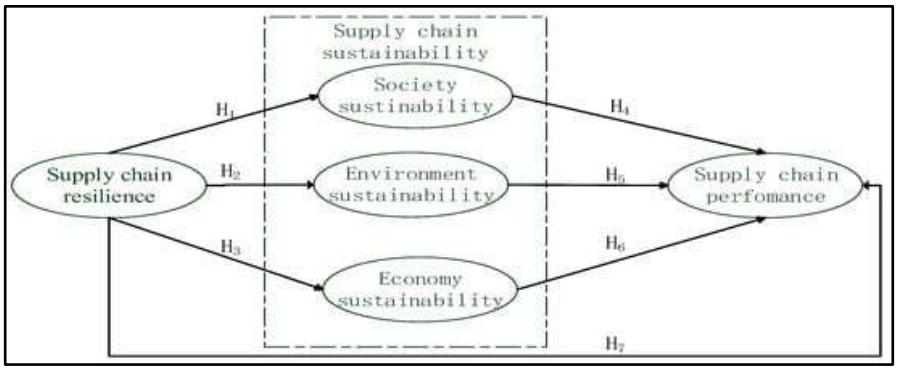

Figure 5: RBV Theory

(Source: Zhu and Wu, 2022)

Digital transformation affords tangible help for those traits. AI and large information analytics enhance agility, permitting corporations to proactively perceive capability disruptions and respond in real time. IoT gadgets offer growth flexibility, offering real-time inventory, transportation, and manufacturing tracking and reallocating as needed (Bayramova *et al*., 2021). Blockchain affords redundancy and believes that through permitting secure, decentralized sharing of information, such that even supposing the event of disruptions, corporations can interact with opportunity providers or routes.

The SCR applies to the post-pandemic context, wherein corporations now face not only health-associated disruptions but also geopolitical, environmental, and financial uncertainties. Firms that embraced virtual transformation have been better capable of preserving operations in the course of the pandemic and at the moment are higher organised for destiny shocks.

2.4 Conceptual framework

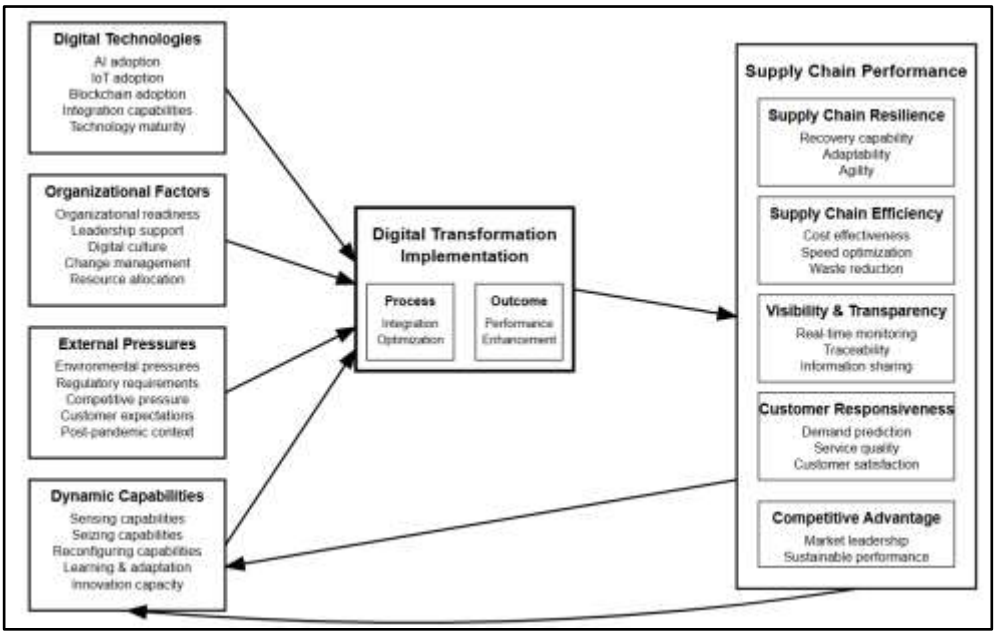

Figure 6: Conceptual framework

(Source: Self-Created)

Utilising concepts discussed previously, the conceptual framework for this study proposes that digital technologies (AI, IoT, blockchain) are strategic resources (they form dynamic capabilities that boost supply chain resilience and efficiency), plus dynamic capabilities. The framework also incorporates organizational readiness, environmental pressures, and institutional pressures to assess the determinants of technology adoption outcomes.

2.5 Literature Gap

The prevailing studies do understand the opportunity of the usage of virtual transformation to enhance delivery chain resilience; there are limits to this frame of literature. First, a majority of research journals isolates one generation in place of thinking about their integrated nature. Second, the qualitative studies on practitioners` views and lived experiences throughout the pandemic are limited. Third, cross-United States of America comparative research is rare; this means that the massive cultural and institutional separation has now no longer been explored.

Lastly, a variety of modern-day frameworks of studies are centred on one enterprise, dismissing the wider applicability of findings throughout sectors.

2.6 Summary

This chapter has reviewed the literature associated with the impact of virtual transformation on the delivery chains due to the pandemic. The literature assessment engaged with the literature to be had at the impact of virtual transformation on resilience-primarily based totally efficiencies and sustainable deliver chains, empirical proof throughout sectors and international locations thru examples and case research, theories, and thoughts such as 'RBV', 'Dynamic Capabilities', 'TOE and SCRES' frameworks, and conceptualisations of a conceptual framework on virtual transformation in deliver chains.

Chapter 3: Research Methodology

3.1 Introduction

This chapter acquaints the reader with the ‘methodological approach’ used to understand the current state of global supply chains and their improvement in efficiency and resilience after the pandemic era, as a result of their digital transformation through technologies such as ‘AI, Blockchain, and IoT’. The matter is capricious and multipartite, qualitative research was decided to be a better choice to enlighten the participants' experiences and industry practices. The methodology chapter draws upon the ‘Research Onion model’ that offers a well-balanced outline for creating sound research designs. The chapter covers the ‘ontological position’ that gives direction to the study, the strategy used for theory creation, the ‘research design’, the ‘quantitative strategy, and the data collection and data analysis methods.

3.2 Research Onion

The research design used in the example is by the well-recognised Research Onion model developed by Saunders *et al.* (2019), which segments the research process into different stages such as ‘philosophy, approach, strategy, choice of method, time horizon, and techniques/procedures. This provides an uninterrupted way that makes sure that there is continuity in terms of logic and that there is alignment between the research problem and the applied methodology. The ‘research philosophy’ is the outermost layer of the research process discussed in the article. It represents the assumptions about the way the knowledge is produced. ‘Interpretivism’ has been utilised in this investigation as it allows an in-depth study of professionals lived experiences and their strategic choices in supply chain disruptions and digital technologies (Saunders *et al.,* 2019). The subsequent layer moving towards the center is the research approach.

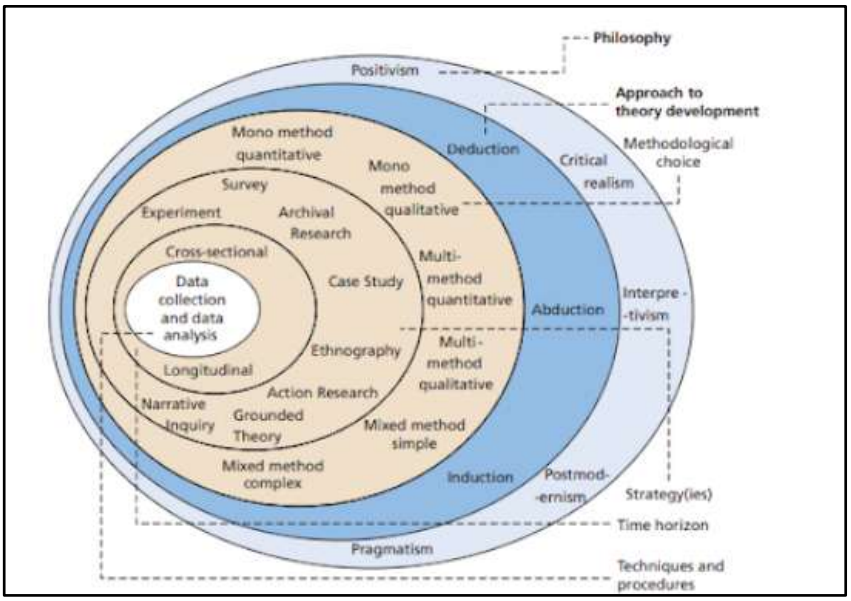

Figure 7: Research onion

(Source: Saunders et al., 2007)

This study will utilise ‘qualitative research’, using ‘semi-structured interviews and closed-ended questionnaires’ (Lim, 2024). This is flexible and detailed in following the use in practice of specific digital tools such as ‘AI, Blockchain, IoT, and the reason for qualitative research’ is to provide evidence of what others have produced or used in this research by examining ‘qualitative data’. The point of ‘methodology’ for this study is ‘mono-method, qualitative, consistent’ with the exploratory aspect of the purpose of the research. ‘Mixed methods’ were included because the study does not attempt to statistically measure but just interpret the subjective meanings of others (Guergov and Radwan, 2021). The advised time horizon is ‘cross-sectional’ in order to obtain a snapshot of the digital transformation strategies post-pandemic.

A ‘longitudinal study’ can yield temporally descriptive information. Finally, ‘surveys and interviews’ as ‘data collection and analysis methods’ are the main techniques. The ‘data collection techniques’ are ‘semi-structured interviews’ with ‘supply chain managers’ and ‘closed-ended surveys’ conducted through ‘Google Forms’ (Pathak *et al.,* 2023). The data will be analysed using thematic analysis on ‘NVivo software’ to support the systematic identification of themes and patterns. Overall, the utilisation of ‘Saunders' Research Onion model’ to shape the

framework for this research approach, such that all ‘methodological decisions’, including philosophical orientation and data analysis, are linked and justified.

3.3 Research Philosophy

The ‘philosophical approach’ to a research investigation has a considerable impact on the design of research, the ‘methodology’, and the ‘interpretation of findings. For this dissertation, looking at how ‘digital transformation’ improves the resilience and efficiency of global supply chains after the pandemic, a use of an interpretivist approach was used. This is because disruptions within the supply chain and digital integration are social constructs, based on experience, which can be deeply understood using quantitative and qualitative measurements. ‘Interpretivism’ is the belief that reality is not a constant. People build it through human relationships and thus can only interpret it from the standpoint of those who experience it (Junjie and Yingxin, 2022). This research will aim to fathom the reasons and the process through which professionals in the supply chain field are adopting ‘AI, Blockchain, and IoT technologies’, as well as the benefits they get by using them as their strategy. It allows researchers to consider the personal contexts of respondents and diverse individual experiences.

‘Supply chain management’ is the field where the usage of this philosophical standpoint will be the most beneficial, as the challenges brought about by the ‘COVID-19’ era and the corresponding way companies responded were not only different in industry but also greatly varied across firms and locations (Bille and Hendriksen, 2022). Different from the ‘positivist’ stance that aims to verify premises with mutually agreed-upon, empirical data, the interpretivist stance accepts that participants' perceptions, choices, and reflections are related to their situations and the social constructs in which the events happen. This is especially important for studying changes in technology in inscrutable marketplaces.

The ‘interpretivism’ accepts the researcher as a constitutive participant in the knowledge construction process. In this research, the researcher must interpret the meaning in participants' responses, determine themes from responses, and relate them to the existing literature. This is in order to maintain some reflexivity to be aware of prejudices and to make clear how the researcher analysed the data. ‘Interpretivist philosophy’ is the correct use of the methodology within the research aims and qualitative approach, as it allows the study to consider the

underlying meanings, motivations, and strategic thinking supporting digital transformation within global supply chains.

3.4 Research Approach

'Research methods' describe how the researcher relates theory and data. There are two major research methods such as 'deductive and inductive. In this dissertation, an 'inductive research method' is applied, with the focus on 'qualitative data collection' and the intention of developing theory or drawing insight from the 'qualitative data' collected (Pilarska, 2021). The 'deductive research method' begins with a 'theory or hypothesis' and then seeks to test it using empirical data.

The 'inductive method' is one that will provide the most favourable results, given that the study is essentially exploratory. In other words, the topic is still being investigated. The topic of supply chain digitalisation has not yet been vastly explored, especially in the wake of the COVID-19 health crisis (Yang *et al.,* 2023). Though there is already some literature on technology like AI, Blockchain, and IoT in supply chains, the capabilities of these tools, the users, and the match of the tools to a particular problem or situation in reality are the subjects of the study.

The study follows a process where themes and patterns emerge naturally from the data by using the inductive method. Especially when dealing with the complex and multiple aspects of such organisational events as shifts in strategy, technology integration, and managerial choices, it becomes a necessity. Also, the real-life experiences of the participants are actually the source of the data that the researcher has to work with. Thus, a full understanding of these events is obtained (Tiwari *et al.,* 2024). Moreover, the 'inductive approach' improves validity in the research findings, particularly when applied in conjunction with 'thematic analysis', since it allows the 'qualitative data' to be fully explored in its complexity and richness. The emergent findings can lead to new frameworks or theoretical perspectives that are outside those anticipated in existing frameworks.

3.5 Research Strategy

The research design, using a 'interpretivism philosophy' and a combined 'inductive-deductive method', opts for a 'mixed-methods research strategy' with the collection of 'qualitative and

quantitative data'. The 'hybrid design' allows sufficient room for the study of complex, many-sided problems, such as the digital transformation impact on supply chain resilience and effectiveness. In the research project, a converged parallel design is employed in that the growth of the qualitative and the 'quantitative research' is done at the same time but yet apart. The data were later merged and were also analysed collectively in order to reach more valid and comprehensive results (Handema *et al.,* 2023). The first strand of the research approach comprises the conduct of 'semi-structured interviews' with supply chain executives of global companies. 'Semi-structured interviews' allow the researcher to go into depth without losing track of the research objectives.

The 'quantitative component' uses a 'schedule-based, closed-ended questionnaire survey'. The 'survey' is conducted online and is aimed at 'supply chain managers' and digital transformation officers in any industry. The survey captures information on the uptake of technology, the way it is used, and the perceived impact on 'operational resilience' (Panya and Nyarwath, 2022). This enables the study to infer general trends and examine the relationships among variables. The use of a 'mixed-methods design' helps to answer the research question from a variety of viewpoints, offering 'statistical generalisability', as well as a qualitative understanding of the context. It also compensates for the weaknesses of each approach individually and improves the general strength and validity of the study. The 'mixed-methods methodology' is best consistent with the 'interpretivism' worldview and the research objectives. It guarantees that both 'quantitative patterns and qualitative observations' are employed to respond to the central research query with strength and significance.

3.6 Research Design

In this study, a convergent 'mixed-methods design' has been employed, thus merging together the 'qualitative and quantitative data' in one research phase to give a complete understanding of the role of post-crisis digital transformation in global product chain resilience and effectiveness (Imran, 2024). In a 'convergent design, both qualitative and quantitative data' are collected separately but in parallel. The 'qualitative aspect' is based on 'semi-structured interviews', which means it is open to the interpretation of the interviewee, and it is personalised. The topics that will be covered include human learning, and these, on a virtual fixer or on a real virtual reality

that the employee feels, all of them are relevant issues, and the researcher must tell the direction of his questions to figure out the need for special training. The ‘quantitative’ part will be conducted using structured ‘online surveys’ that can easily reach a large sample of people and enable the determination of the intensity of adoption, the level of perceived impact, and the differences between sectors.

Each set of data collection is analysed seriatim ‘thematic analysis for interview’ data and descriptive and inferential statistics for survey data. The findings are then synthesised in the following chapter, in which they are compared and discussed in conjunction with one another in order to develop a storyline. ‘Triangulation of data’ helps the researcher to authenticate and corroborate the conclusions about the topic under study. The purpose of the selection of this design also relates to the purpose of the research. Understanding how digital transformation reshapes supply chains is related to knowing not only how often certain technologies are used, but also why and how they are implemented in practice, or the essence of the digital transformation process. The schema came to provide both depth and breadth for connecting research questions. Efficient collection of suitable data through systematic study can be combined with sound analysis, compared to longitudinal studies, considering timeframes for processing the respective researcher and practitioner information.

3.7 Data Collection Method

This study delved into the extent to which the ‘digital transformation’ is responsible for the success of the global supply chain in terms of the post-pandemic growth of resilience and efficiency by employing a ‘mixed-methods data collection approach’ that merged ‘qualitative and quantitative methods. The combination of these two ‘methods’ makes it possible for the research to not only investigate the critical elements of the issue but also validate the findings amongst a larger population.

‘Semi-structured interviews’ with five supply chain managers who work for multinational organisations were used to collect qualitative data. Recruitment was done using purposive sampling after their involvement in digital transformation programs had been established. Each of such ‘interviews were performed by asking seven open-ended questions, which were designed to explore how the participants view the use of AI, Blockchain, as well as ‘IoT in their SC

operations' (Adeoye-Olatunde and Olenik, 2021). Issues broached were so broad as to range from motives for going digital to implementation challenges to effects seen to plans for the future. The 'interviews' were conducted remotely (via Zoom or Microsoft Teams) and lasted from 30 to 45 minutes. The 'interviews' were audio-recorded after obtaining informed consent and transcribed for analysis afterwards.

The 'quantitative data' was collected through an online survey consisting of 13 questions with fixed answer choices, sent to 53 supply chain experts drawn from 'manufacturing, logistics, pharmaceutical, and technology sectors. The 'survey' was disseminated via 'Google Forms' and in the form of 'multiple-choice and Likert-scale questions. Ultimately, the main issues surveyed were the number of digital tools being used, how the firm perceived efficiency and resilience, the types of technology humans used, and the readiness of the organisation (Kircher and Zipp, 2022). The 'questionnaires' were based on studies from the literature and were pre-tested by administering them to a small group before dissemination. The combination of 'interviews and questionnaires' allowed the research process to obtain both narrative understanding and quantitative data. This mix of depth and generalisability created better reliability of the study and validity of the output.

3.8 Data Analysis Method

The research used a 'mixed-methods design', and two distinct analytic methods were used such as 'thematic analysis' for the 'qualitative interview data and descriptive statistical analysis' for the 'quantitative survey data' (Ghorbanian *et al.,* 2021). They were discovered in isolation from one another; however, were linked at the 'interpretation' stage to allow for a balanced understanding of how digital transformation has impacted supply chains.

In order to conduct qualitative interviews, thematic analysis was used for data analysis. Here, 'Braun and Clarke's six-stage model' was utilised, namely familiarisation, initial code generation, search for themes, review of themes, theme naming and defining, and report writing. Signs of the 'six themes' were detected. The 'NVivo software' was chosen as a computer program through which the code has been generated along which the descriptive analysis can be developed. Thus, the participants' responses were organised, concepts that reappeared were detected, and the themes that included all the others were formed (Allsop *et al.,* 2022). The initial

coding phase was inductive so that the themes could be richly drawn from the data without forcibly forced. The labels were not determined before the coding; that is, they were not pre-determined. Awareness of the main topics includes ‘Advancing visibility through IoT’, ‘Automation through AI,’ ‘Trust and traceability through Blockchain’, and ‘Organisational Adaptability’. ‘NVivo’ yielded rigour and trustworthiness to the analysis as it offered clarity and consistency that was necessary for multiple coders by logically assembling and managing the small datasets.

The analysis of the ‘quantitative survey responses’, 53 responses were exported from ‘Google Forms’ into ‘Microsoft Excel’ for some basic structuring before analysing the data through descriptive statistics. Using ‘frequency, percentages, and cross-tabulation’, it was able to examine any patterns that occurred in responses to the 13 ‘closed-ended questions. It then began considering the degree of uptake of digital technology, changes in resilience, levels of satisfaction with technology investment, and challenges to the implementation of change. The ‘statistical analysis’ allowed generalised conclusions to be made over a broader population and informed richer narratives about the ‘interviewees’ stories (Goyal and Deshwal, 2022). Output from each analysis was then collated and compared to look for overlap and divergence. The ‘method of triangulation’ increased the trustworthiness of the study through an examination of two separate data sources. Overall, the ‘meta-synthesis’ provided in-depth ‘qualitative insights’ as well as quantitative generalisability in support of robust and actionable conclusions.

3.9 Sampling

Participants with relevant experience in supply chain processes and digital transformation were selected purposively for this study. Five practitioners were chosen from international companies that have already engaged technologies, including ‘AI, Blockchain, and IoT’ in their supply chain systems. These were supply chain managers, digital transformation leads and so their inputs would be relevant and experiential.

In the ‘quantitative survey’, 53 individuals had been randomly selected from numerous industries, consisting of manufacturing, logistics, healthcare, and retail. All individuals needed to have at least years of experience in delivering chain control and modern or current enjoy in virtual transformation projects (Chauhan and Sahoo, 2024). ‘Inclusion’ standards warranted that

everybody answering had something significant to mention approximately the study's question, and ‘exclusion standards' precluded individuals’ without an on-the-spot or current enjoy of deliver chain digitalisation. This unique sampling approach extended the relevance, credibility, and validity of facts gathered.

3.10 Ethical Consideration

The research was carried out according to the ethical guidelines for the National College of Ireland and in line with the general principles of academic honesty. Ethical permission from the appropriate research ethics committee was sought and granted before the data collection. All participants received an information sheet and consent form that presented in clear and explicit language the purpose of the research, the voluntary nature of the participation, and the right of the participants to withdraw at any point in the study without any penalty. Anonymity and confidentiality were maintained throughout the process of research process. During the transcription process, the interview data were anonymised, and no named data was associated with respondents to the surveys. All data were securely stored, using encrypted password-protected devices, with access afforded only to the researcher. Furthermore, the participants were informed how their data would be used, in compliance with the ‘General Data Protection Regulation (GDPR)’ (Vlahou *et al.,* 2021). Ethical considerations ensured that the participants were treated with dignity, their privacy respected, and that the research was conducted responsibly and ethically.

3.11 Summary

This chapter has presented a comprehensive research methodology used to investigate ‘digital transformation’ for the enhancement of resilience and efficiency of ‘international supply chains’ in the ‘post-pandemic’ scenario. The study adopted an interpretivism approach, using both ‘qualitative semi-structured interviews’ and ‘quantitative closed-ended questionnaires (mixed methods)’. Thus, the richness of context could be combined with empirical generalisation.

The research ‘philosophy, approach, strategy, and design’ choices were systematically clarified with the help of the ‘Research Onion model’ in this study. ‘Theory’ building from ‘interview data’ was ‘inductive’, and ‘deductive research’ was employed to investigate assumptions

through survey returns. Rigorous analysis of diverse data types was made possible through ‘thematic analyses in ‘NVivo (for interviews) and descriptive statistics (for surveys)’. ‘Sampling techniques’ ensured that industry participants have relevant, “real-world” experience in activities within the ‘digital supply chain’. Ethical issues describe that informed consent, privacy, and confidentiality were sufficiently addressed to ensure ethical research practices. Collectively, the implemented approach provides a robust foundation for ‘modelling complex’, ‘dynamic supply chain’ tasks. The openness permits research to include in-depth practitioners’ perspective, as well as being measurable by industry trends, and provides a basis from which a complete, credible analysis can be conducted in the following chapter.

Chapter 4: Findings and Analysis

4.1 Introduction

The present chapter is going to analyse the effects of COVID-19 on supply chain practices, predict the role digitalisation will play in efficiency, visibility and sustainability, and propose the obstacles and facilitators of the former. In addition, the chapter will discuss the information obtained after interviewing the industry specialists using a quantitative and qualitative tool and thus interpret it according to the research goals. The analysis shall create a profound exposition of how the use of digital tools is going to transform the supply chains in order to make them more resilient and competitive in the long-term perspective.

4.2 Data Findings and Analysis

Quantitative Analysis

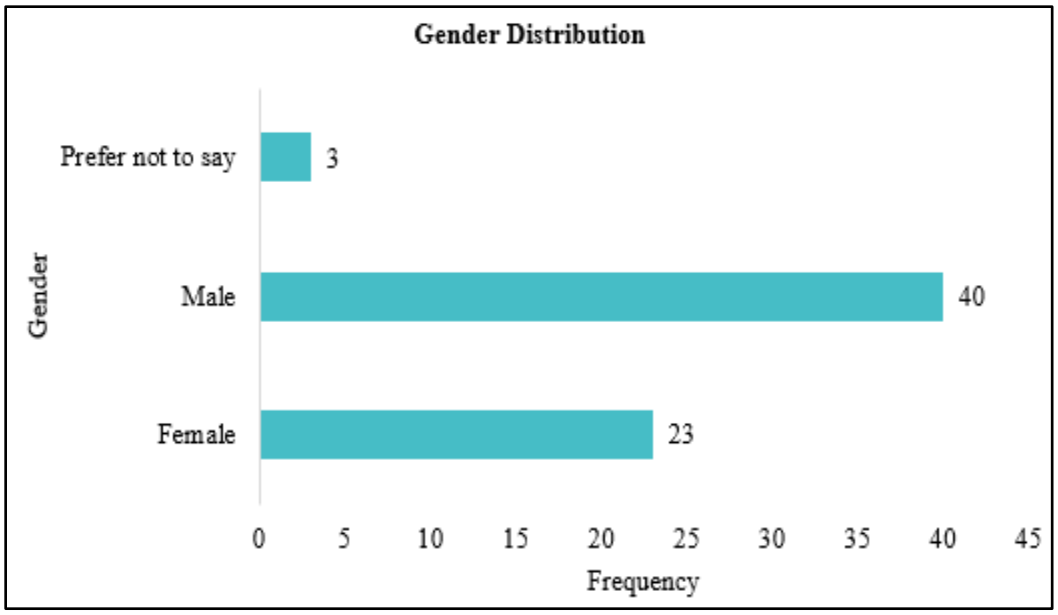

Figure 8: Gender Distribution Graph

(Source: Retrieved from MS Excel)

The graph has revealed that 40 respondents are male, and 23 respondents are female. This indicates a male-dominated sample, possibly reflecting broader gender trends in the supply chain workforce.

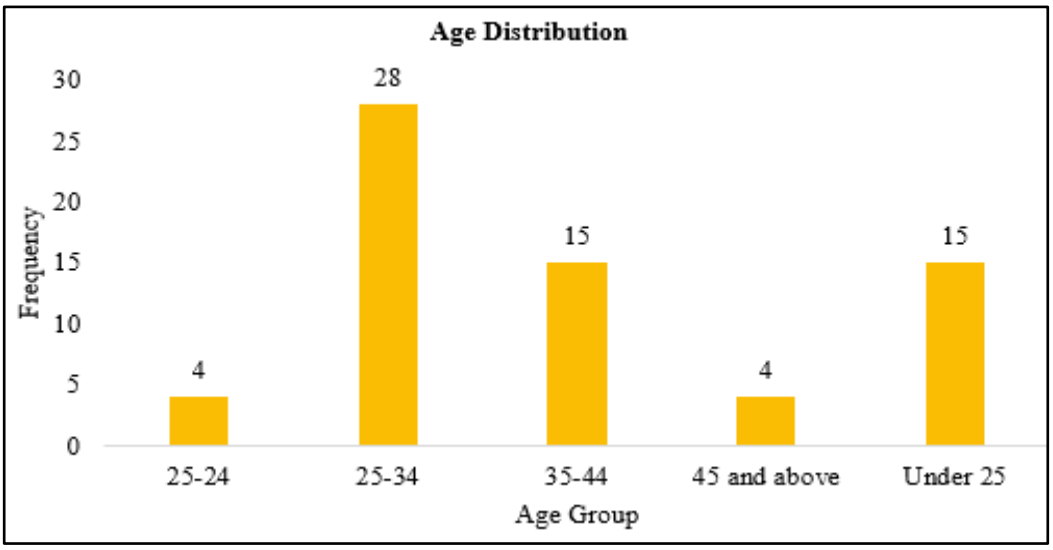

Figure 9: Age Distribution Graph

(Source: Retrieved from MS Excel)

From this graph, it has been shown that most respondents have fallen within the 25-34 age group, followed by 35-44 and under 25. This suggests that mid-career professionals have predominantly participated in the survey.

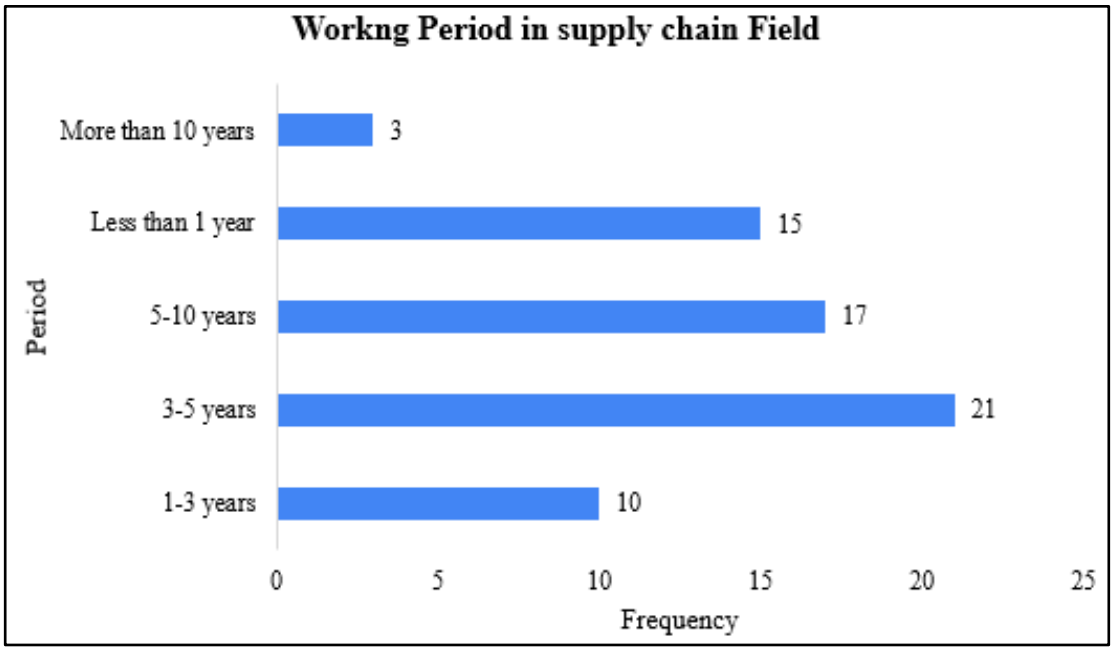

Figure 10: Working Period in Supply Chain Field

(Source: Retrieved from MS Excel)

This plot indicates that 21 respondents have been working for 3-5 years in the supply chain field. 17 respondents have been working for 5-10 years, and 15 respondents have been working for less than 1 year in this field.

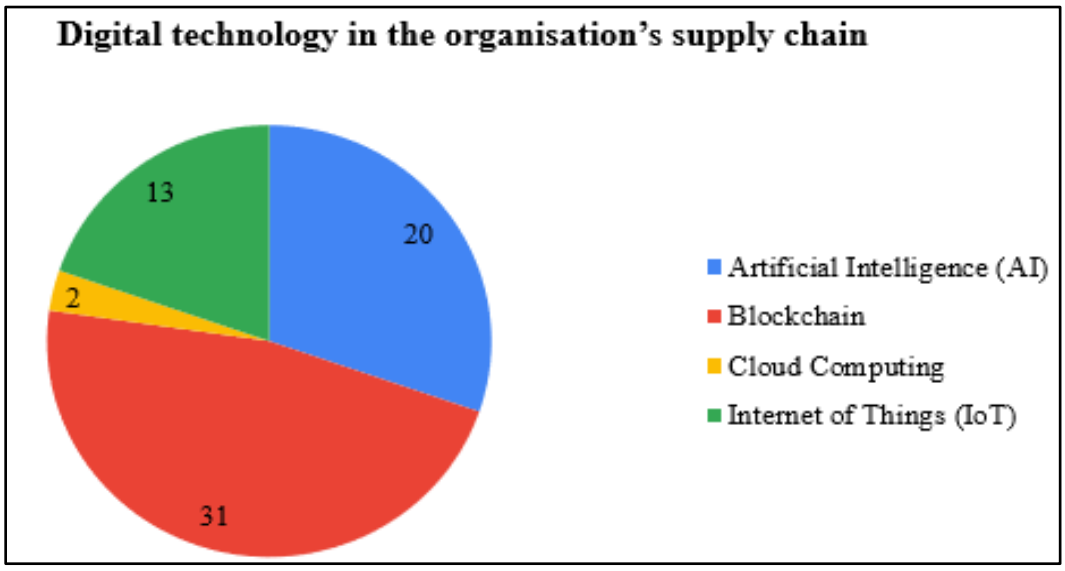

Figure 11: Digital Technology in the Supply Chain

(Source: Retrieved from MS Excel)

According to this graph, it can be said that 31 respondents believe that blockchain technology has the most impact on the organisation's supply chain. 20 respondents believe that AI can have an impact on the organisation's supply chain operation.

	Q5. Is the organisation prepared for future supply chain disruptions?	Q6. Has the organisation widely adopted AI, Blockchain, and IoT in its supply chain?	Q7. Does digital transformation improve operational efficiency?	Q8. Do digital technologies strengthen post-pandemic supply chain resilience?	Q9. Does the organisation provide sufficient training for digital adaptation?	Q10. Does real-time digital visibility improve supply chain decision-making?	Q11. Does Blockchain improve transparency and trust in the supply chain?	Q12. Do IoT devices enhance logistics tracking and inventory monitoring?	Q13. Do digital investments align with long-term supply chain goals?
Mean	4.52	3.73	3.83	3.85	3.79	3.76	3.89	3.76	3.82
Median	5	4	4	4	4	4	4	4	4
Mode	5	4	4	4	4	4	4	4	4
Standard Deviation	0.66	0.81	0.81	0.83	0.85	0.91	0.79	0.82	0.89
Kurtosis	-0.05	2.87	1.64	3.56	1.84	2.38	4.92	2.66	1.84
Skewness	-1.04	-1.39	-0.91	-1.56	-0.81	-1.37	-1.76	-1.22	-1.10

Table 2: Descriptive Statistics

(Source: Retrieved from MS Excel)

The descriptive statistics have informed that the majority of the respondents have agreed to all the statements, with the median and mode values always coinciding with 4. The highest mean score of 4.52 for Q5 has shown high perceived preparedness against the occurrence of supply-chain disruptions in the future. The standard deviations have been relatively low, which indicates an apparent respondent consistency. Particularly, Q11 has recorded the most kurtosis of 4.92, which suggests that a more peaked distribution will have extreme agreement with the role of Blockchain in trust and transparency. This data has been a positive interpretation of the attitude towards digital transformation and its contribution to the supply chain resilience and efficiency.

SUMMARY OUTPUT				
Regression Statistics				
Multiple R	0.397548323			
R Square	0.158044669			
Adjusted R Square	0.144889117			
Standard Error	0.764998522			
Observations	66			
ANOVA				
	df	F	Significance F	
Regression	1	12.01353381	0.000948563	
Residual	64			

Total	65			
	Coefficients	Standard Error	t Stat	P-value
Intercept	1.605319149	0.653995919	2.454631754	0.016832471
Q5. Is the organisation prepared for future supply chain disruptions?	0.496808511	0.143335458	3.466054502	0.000948563

Table 3: Regression Analysis

(Source: Retrieved from MS Excel)

Dependent Variable: Q8. Do digital technologies strengthen post-pandemic supply chain resilience?

Independent Variable: Q5. Is the organisation prepared for future supply chain disruptions?

Level of Significance (p-value): 0.05

Obtained Significance Level: 0.00094 (Statistically Significant)

This analysis has shown that there exists a statistically significant positive correlation between the organisational readiness to be prepared for the possible disruptions occurring in the future and the perceived post-pandemic supply chain resilience brought about by digital technologies. The 0.497 presented as a coefficient has also implied that as preparedness increases by 1 unit, resilience has also gone up by almost 0.5 units. The statistically significant result has been determined with a p-value of 0.00094, as it is much lower than 0.05, which is the level of significance. Model simplicity has been taken into consideration by the adjustment of the R-squared, which supports reliability. This outcome has shown that disruption-ready organisations also felt a higher level of post-pandemic resilience due to the digitally transformed supply chain.

SUMMARY OUTPUT				
Regression Statistics				
Multiple R	0.370982051			
R Square	0.137627682			
Adjusted R Square	0.124153114			
Standard Error	0.762661237			
Observations	66			
ANOVA				
	df	F	Significance F	
Regression	1	10.21388495	0.002165676	
Residual	64			
Total	65			
	Coefficients	Standard Error	t Stat	P-value
Intercept	2.449367089	0.443100759	5.527788067	6.386E-07

Q6. Has the organisation widely adopted AI, Blockchain, and IoT in its supply chain?	0.371308017	0.116181999	3.195916919	0.0021657

Table 4: Regression Analysis

(Source: Retrieved from MS Excel)

Dependent Variable: Q7. Does digital transformation improve operational efficiency?

Independent Variable: Q6. Has the organisation widely adopted AI, Blockchain, and IoT in its supply chain?

Level of Significance (p-value): 0.05

Obtained Significance Level: 0.002 (Statistically Significant)

In this analysis, a statistically significant outcome has been found in a positive correlation between digital technology adoption and achieving operational efficiency with digital transformation. R-Square stands at 0.138, which means that 13.8% of the variability in the efficiency of operations has been described by the use of the AI, Blockchain, and IoT. The coefficient 0.371 indicates that operational efficiency has improved by nearly 0.37 with every one-unit increase in the adoption of digital. The p-value of 0.002, which is quite a long way below 0.05, has also revealed that the relation is not less than significant. It has been shown that the model is consistent since the adjusted R Square has taken into consideration the simplicity of the model. The intercept value of 2.449 implies that, despite the poor adoption, there has been a moderate level of efficiency. It can be said that the higher embracement of digital technologies has enhanced operational efficiency in the supply chain operations.

Regression Statistics				
Multiple R	0.337242321			

R Square	0.113732383			
Adjusted R Square	0.099884451			
Standard Error	0.807014508			
Observations	66			
ANOVA				
	df	F	Significance F	
Regression	1	8.212950991	0.005622115	
Residual	64			
Total	65			
	Coefficients	Standard Error	t Stat	P-value
Intercept	2.474683544	0.468869694	5.277977176	1.66106E-06
Q6. Has the organisation widely adopted AI, Blockchain, and IoT in its supply chain?	0.352320675	0.122938671	2.865824662	0.005622115

Table 5: Regression Analysis

(Source: Retrieved from MS Excel)

Dependent Variable: Q9. Does the organisation provide sufficient training for digital adaptation?

Independent Variable: Q6. Has the organisation widely adopted AI, Blockchain, and IoT in its supply chain?

Level of Significance (p-value): 0.05

Obtained Significance Level: 0.005 (Statistically Significant)

Regression analysis has proved a statistically significant positive correlation between the implementation of digital technologies and the relevant training of the personnel on digital adaptation. The R Square value of 0.114 indicates that 11.4% of the variation in training support has been explained by the level of digital adoption within the organisation. The coefficient of 0.352 indicates that the change in the training support at the one-unit output of a higher degree of adoption of digital technology increased by about 0.35 units. The p-value of 0.005, which is less than the significance level of 0.05, has ascertained that the model is statistically significant. The adjusted R Square depicts the validity of the model after considering explanatory simplicity. The intercept value of 2.47 has reflected a baseline level of training even in the absence of widespread digital adoption. This result has revealed that organisations that embrace progressive technologies have also been inclined to offer more training in order to guarantee effective embrace of digitalisation.

Qualitative Analysis

Theme 1: Impact of COVID-19 on the supply chain

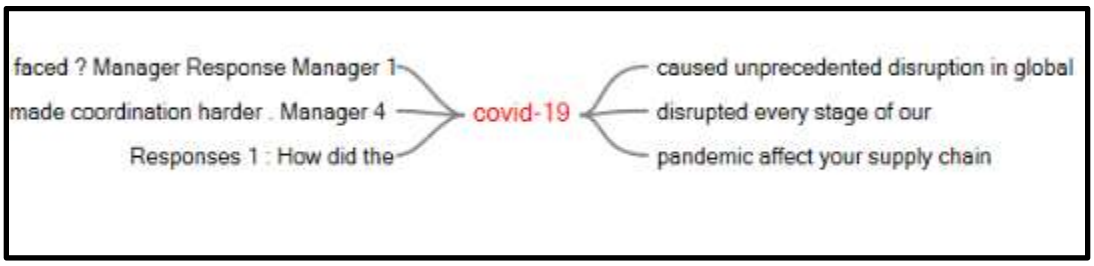

Figure 12: Word Tree

(Source: Retrieved from NVIVO)

Findings indicate that the COVID-19 pandemic significantly and extremely affected the operations of supply chains of business organisations, as observed by all five managers of disruptions in supply chains. One of the common aspects of responses is the extreme logistical impact of factory closures and port congestion, as well as decreased air freight resources, contributing to long lead times and transportation costs. Managers 1 and 2 highlighted the lack of inventory and rising freight prices to show how global supply chains were under pressure due to operational and financial pressure. Moreover, the issue of demand unpredictability was identified as a serious concern, as Manager 1 reported the rapid changes in consumer behaviour, and Manager 3 mentioned the appearance of demand jumps in goods that are in demand and significant drops in other categories. Another major problem that was identified by Managers 1, 3, and 4 was the absence of real-time visibility and integration of all supply chain partners, thus hampering planning and coordination. The fact that reporting was done manually and no digital tracking systems existed also contributed to the slowness of responses (Manager 4). Moreover, the observation made by Manager 5, regarding the vulnerabilities of the suppliers, suggests the dangers of being too dependent on the suppliers of certain regions, and the inaccuracy of increases in the inventory indicates the operational inefficiency due to the crisis.

Comprehensively, the information shows that the pandemic strategically brought out the shortcomings of the supply chains, such as reliance on international suppliers, under-digitalisation, and a lack of risk mitigation programs (Shen and Sun, 2023). Such results underline the necessity to invest more in digital tools to enhance real-time visibility, diversify insights on sourcing strategies, and create resilience. With the issue of challenges addressed, organisations will be able to prevent further disruptions in the future and establish more technology-driven and agile supply chains.

Theme 2: Ways digital transformation improves operational efficiency, visibility, and sustainability in supply chain management.

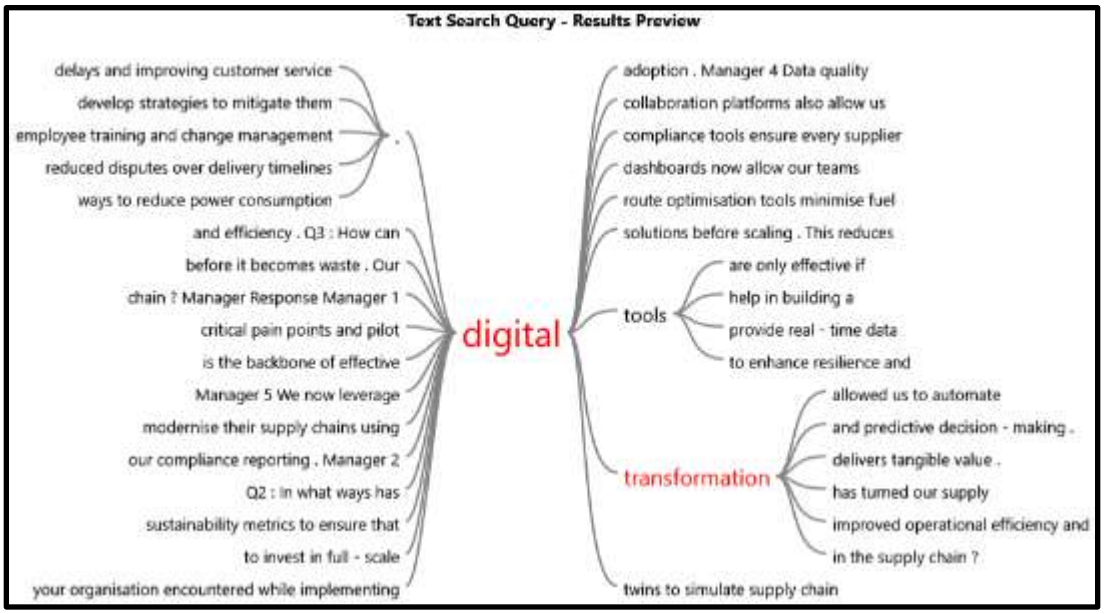

Figure 13: Word Tree

(Source: Retrieved from NVIVO)

The results show that operational efficiency and visibility throughout the supply chain have improved significantly due to digital transformation, as all five managers have confirmed. Automation and even artificial intelligence (AI) have been so instrumental in facilitating ease in operations. Manager 1 also emphasised the ability of AI-driven demand forecasting and automated inventory management that helped to optimise overstocking and out-of-stock scenarios, and that real-time tracking of shipments was able to eliminate transportation blind spots, resulting in more efficient decision-making and reduced operations costs. Equally, Manager 4 highlighted the application of AI-powered demand-planning tools and automated warehouses that led to a 15% decrease in operational expenses and turned the supply chain into a proactive mode.

Cloud was identified as a factor directly causing visibility, as it allows to retrieve the information on the full supply chain in real time, thus creating good conditions to conduct predictive analytics and prevent disruption proactively. Manager 3 continued that the IoT sensors and blockchain technology have enhanced transparency, increased the accuracy of the inventory, decreased the number of disputes, and the digital dashboards provided monitoring of the performance metrics in real-time, increasing responsiveness. To a further extent, Manager 5

highlighted the relevance of digital twins and machine learning, helping to simulate multiple scenarios and minimise forecasting errors by 20% which enhanced risk mitigation and operations resilience. All these findings prove that digital transformation has transformed supply chains into networks where they were once disintegrated and reactive systems (Stroumpoulis and Kopanaki, 2022). The enhanced efficiency and visibility that comes with the integration of AI, IoT, blockchain and cloud-based platforms will increase resilience by allowing organisations to predict, prevent and respond to disruptions within an organisation and be able to provide a competitive edge.

Theme 3: Main barriers and enablers

The involvement of organisational and technological issues in the implementation of digital transformation in supply chains has been identified in the analysis. Four out of the five managers named funding restrictions as one of the major problems, especially when it comes to SMEs. A similar experience has been described by Manager 2, who said that it was very challenging to get the executive buy-in since the ROI of investing in AI or blockchain is not clear. On the other hand, Manager 3 and Manager 5 pointed to the fact that legacy systems are incompatible with modern technologies, which reflects the problems of integration. Another common theme has resistance to change among employees who feared losing their jobs, or employees who did not have skills in digital. In contrast, Manager 4 mentioned quality of data and cybersecurity as technological challenges that hampered the process of implementation.

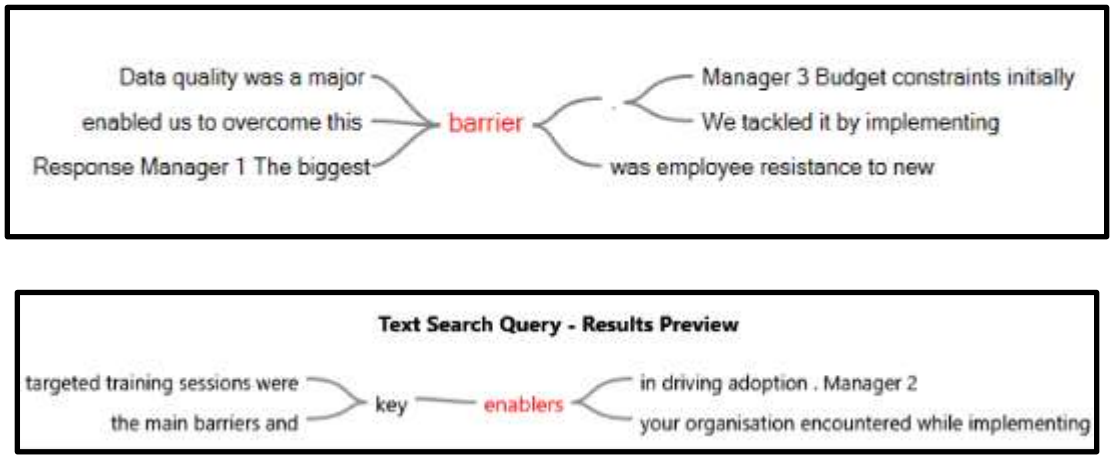

Figure 14: Word Tree

(Source: Retrieved from NVIVO)

Nevertheless, the interviews also identified a couple of enablers that contributed to the process of digital transformation. Manager 1 named the commitment of leadership as one of the key factors that facilitated certain successful outcomes and assisted in attracting the required investments. It has discussed implementation involving pilot programs that demonstrated an initial value and made the acquisition of organisational buy-in possible. Apart from this, training programs and third-party logistics provider alliances have also been considered as a facilitating factor since they minimise the technical complexity of implementation. On the whole, these observations indicate the effectiveness of digital transformation and reveal that every organisation will need to have an internal culture, a clear plan of action, and good leadership to remove both operational and psychological challenges.

Theme 4: Effective strategies for improving supply chain management.

The interviews have identified several functional strategies that firms are incorporating to enhance the management of the supply chain in the face of digital transformation. According to Manager 1, the implementation of predictive analytics resulted in the opportunity to plan the demand better and prevent shortages as well as stockouts. Besides, Manager 2 claimed the implementation of cloud-based dashboards to combine information on data from various suppliers, which led to making better decisions and increased speed of actions. In contrast, Manager 4 suggested that IoT-based real-time monitoring tools have greatly enhanced the visibility of transport and the warehouse processes.

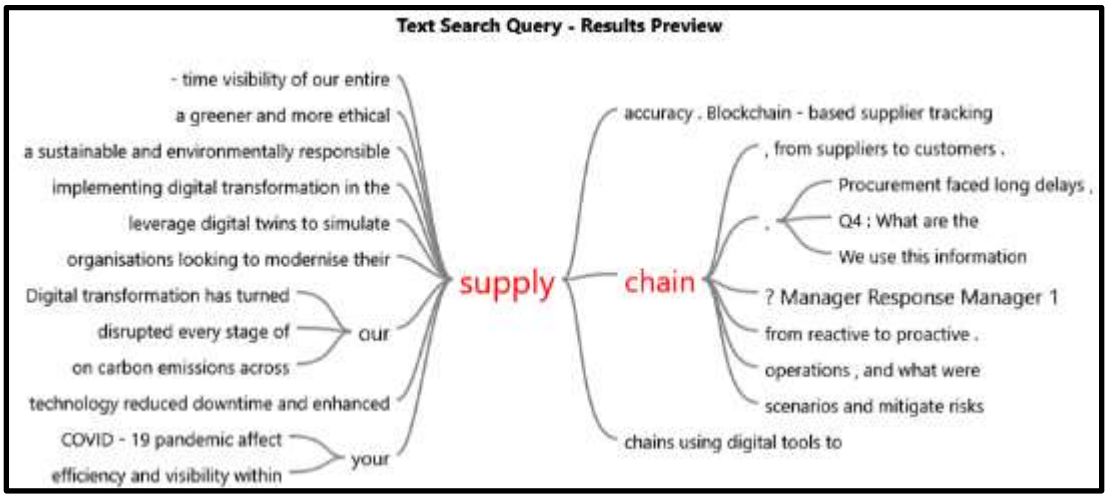

Figure 15: Word Tree

(Source: Retrieved from NVIVO)

Manager 5 focused on the need to construct digital twins to create simulations of various conditions in the supply chain, thereby preparing to respond to a disruption and added that the process of responding to the risk improved by 20 per cent. It has outlined the implementation of blockchain to monitor the work of suppliers and guarantee compliance with the requirements of environmental regulations, predominantly in the context of locating raw materials. Some managers also concurred that cooperation with technology vendors, as well as joint digital initiatives with logistics partners, as these are contributing to achieving successful implementation. The mention of training employees and cross-functional teams as some of the major steps to maintain the improvements was made. These will enable a transition to take place from reactive to proactive supply chain management, with organisations having the capabilities to anticipate disruptions, enhance responsiveness, and develop long-term resiliency with the integration of technology and continuous learning.

The best approaches to the problem of optimising supply chain management refer to the adoption of digital tools, including AI, IoT, and blockchain, to strengthen the supply chain's real-time visibility, forecasting power, and decision-making. Companies need to come up with effective roadmaps involving pilot projects in areas that have a significant impact, followed by the expansion of the change processes. Enhanced data governance will guarantee security and accurate information, whereas the tech partners and suppliers will enhance transparency and integration. Such resistant behaviour should be overcome through workforce training and change management. Furthermore, sustainability initiatives, like carbon tracking and energy optimisation, can be incorporated to create resilience in the long term. As the performance is measured regularly with the help of KPIs, continuous improvement and alignment with the idea of organisation's objectives can be maintained.

4.3 Discussion

Supply chain functionalities of business entities in the world were badly interrupted by the COVID-19 pandemic, demonstrating a structural weakness in the current logistics and

procurement systems (Magableh, 2021). Shipping and freight movement were delayed in unprecedented ways due to lockdowns, restrictions in the border area, and problems with port congestion. Organisations experienced shortages in materials, and this hit mainly organisations with single-source suppliers located in highly affected areas like China and Southeast Asia. Shortage of labour related to health restrictions additionally contributed to ineffectiveness in operations, especially in warehousing and transportation. Shifts in demand were also highly disruptive, and some industries thrived (healthcare and e-commerce), whereas others plunged in terms of demand (automotive and luxury goods).

Another severe issue was that the multi-tier supply chain lacked visibility in real-time and was, therefore, a drawback in decision-making before they occurred (Hammerer, 2024). Most firms have realised that they were highly dependent on manual procedure-driven systems and old legacy systems, which hindered their capability to be dynamically responsive to disruptions. This created a situation where there was a stockout where it was not needed, and lots of stockouts where there was an end need. There was also increasing pressure on the cost of freight, container shortages and unexpected changes in the regulations governing the trade. Nevertheless, the pandemic was used as an agent of change as it made organisations review their supply chain approaches. The companies started to diversify their supply chain, with nearshoring being a top priority to minimise their reliance on a specific area and double down on digitalisation. Finally, COVID-19 also transformed the global supply chain by not only focusing on cost-efficiency but also on creating resiliency, agility, and technology integration against future disturbances.

Digital transformation has become one of the foundations of modern supply chains' modernisation in the post-pandemic world. Organisations also have massive potential to improve the efficiency and visibility of their operations by incorporating new technologies like artificial intelligence (AI), Internet of Things (IoT), blockchain and cloud-based platforms. Automation in the fulfilment context could entail using robotic process automation (RPA) or a warehouse management system to accelerate the order fulfilment process and reduce human error by automating mundane tasks (Chakraborty and Mateen, 2025). With the use of predictive analytics based on AI, forecasting the demand can be accurate, leading to companies balancing their stocks, preventing oversized production, and saving working capital. To illustrate, machine learning programs can be used to process past sales, market dynamics, and exogenous factors in

order to ensure procurement and manufacturing cycles work with optimal efficiency. More than that, digital twins, virtual models of the supply chain process, enable the study of the supply chains, provide opportunities to simulate the events, and work out bottlenecks to provide data-driven decisions to increase the effectiveness.

Real-time data integration has transformed the way things are seen in the supply chain. Supply chain management systems allow managers to monitor shipments and vendor performance and view inventory volumes worldwide using cloud-based dashboards. The visibility is also improved through the use of IoT devices to give real-time tracking of the location and state of goods during transport (Adeusi *et al.*, 2024). The Blockchain technology provides the stakeholders with an immutable, transparent record of the transactions, guaranteeing them in the role of trusting each other, as well as minimising their disputes concerning the delivery schedule or quality factors. It is actually because of this end-to-end visibility that there is a way to make decisions more quickly and more informed decisions in the end, which reduces risks and postponements.

Digital tools are vital as far as sustainability is concerned in terms of less impact on the environment. With advanced analytics, one can be able to cut down transportation routes, reducing fuel consumption and emissions. Energy monitoring in the warehouse with the help of IoT contributes to the elimination of useless energy consumption, and demand planning that is carried out by using AI helps to avoid waste by synchronising production with the real pattern of consumption (Ayoola *et al*., 2024). In addition, blockchain increases the traceability of the suppliers so that the environmental and ethical standards can be met, especially in the food and apparel industries. Carbon tracking tools and sustainability dashboards have since enabled companies to report and measure their environmental performance and align with the regulatory stipulations and the social responsibility aspirations of a company. Efficiency, visibility, and sustainability incorporated into digital transformation not only enhance the daily work of supply chain operations but also create resilience and competitive values in the long term, using the constantly changing global market as leverage.

As good as it sounds, the implementation of digital transformation in supply chains has its issues. Among the major obstacles, there is a lack of funds to adopt technology. Small and medium-

sized enterprises (SMEs) may not find it easy to attach an ROI to the preliminary investment expenditure of AI, blockchain or IoT infrastructure (Khan *et al*., 2023). Another major challenge that awaits integration with legacy systems, many organisations still use old ERP systems, which may not be compatible with the newer technologies. The other barrier is organization resistance to change. Traditional workers who are more used to the old-fashioned ways of doing things in the supply chain can also be reluctant to adopt new technology due to the fear of job loss or encountering difficulties along the way because of skills shortages. The quality of data and security is also a question. Ineffective analytics and forecasting tools are compromised by poorly managed data, whereas the potential of the breach of data breaches through digital connectivity in the supply chain network escalates with the rates of connectivity.

Nevertheless, there are various enablers that can propel effective digital transformation. There needs to be great leadership commitment and a sensible digital strategy to overcome the resistance and get stakeholders aligned (Reynolds, 2024). Pilot programmes and staged implementations aid in proving that new technologies are worth the investment and support by making it easier to get buy-ins. Moreover, government incentives, industry collaborations may add financial and technical assistance, particularly to SMEs. The training and change management plans are also important facilitators. With the proper training of employees and the development of a culture of innovation, it is possible to accelerate the process of digital adoption. Furthermore, alliances with tech providers and third-party logistics providers (3PLs) with established high-level digital capacities can help decrease the scale of the transformation and associated complexity.

In the case of companies that want to enter the new era of supply chain modernisation and make it sustainable following the pandemic, systematisation and a long-term plan for implementing digitalisation are essential concepts. The initial approach is to commence with a proper roadmap. Businesses ought to undertake a proper evaluation of the current operation of their supply chain, identify points of pain and prioritise where digital tools will be of maximum value (Mohsen, 2023). Instead of trying to overhaul with an all-out change, companies ought to first put in place pilot projects in areas where the change will have the greatest impact, like forecasting demand or tracking shipments. In case of success, such initiatives will be able to be scaled throughout the organisation.

Secondly, data governance will have to be made a priority. All digital implementations, whether AI-powered analytics or blockchain tracking, need to produce and process clean, reliable data. To protect sensitive information in supply chains, companies ought to invest in an intelligent data management system, set quality standards on data and also adhere to specific cybersecurity measures (Osunkanmibi *et al.*, 2025. Third, it is critical to cooperate with technology partners. The implementation can be faster and less expensive by taking advantage of software providers and cloud providers, as well as logistics technology firms. Moreover, cooperation with suppliers on common online platforms enhances trust and transparency, which is extremely important, as it increases risk management efficiency. Fourth, organisations should invest in developing their workforce. The resistance can be defeated by training the employees on how to use the digital tools efficiently and in a manner possible to involve them in the process of change. More effective decision-making can also be achieved by forming cross-functional teams that integrate the skills of IT, operations and procurement. Fifth, sustainability should also be part and parcel of the digital transformation strategy of the organisation.

Carbon tracking dashboards, energy optimisation systems, and supplier compliance monitoring tools not only work to make companies perform better regarding environmental performance but also help boost the brand image and comply with regulations (Zampou *et al.*, 2022). Lastly, performance measurements must be defined. In order to measure the effectiveness of digital transformation, every business should monitor the effects that it makes in terms of cost reduction, lead times, inventory evolution and green indices. Continuous improvement activities and regular reviews will help ensure that digital transformation is not out of the way of elevating business objectives and adjusting to market conditions. Such strategies enable organisations to create effective, adequate, and efficient supply chains that are able to withstand any upcoming disruptions.

Although digital technologies have improved supply chain visibility, responsiveness and sustainability, this has not been equal with consideration to all organisations. In addition, larger firms, including Pfizer and Alibaba, should implement emerging tools, such as blockchain and digital twins, as digital maturity and infrastructure accompanied by organisational performance and productivity (Chen et al., 2024). Conversely, smaller firms encountered obstacles in the form of funding, technical expertise and system integration, underlining the significance of

organisational preparedness, which is evidenced by the Technology-Organisation-Environment (TOE) framework. Moreover, one of the issues that is increasingly being raised is the issue of excessive use of computer systems. Since AI and IoT have enhanced forecasts to be more accurate and observation, the use of only AI without human supervision can potentially fail or commit mistakes in predicting, as well as be biased. This is an indication that hybrid systems to be used that involve automation and human judgement. In addition, the supply chain strategies of the future have to consider the possible external shocks, including ESG regulations and geopolitical changes. These results lead to the idea that digital transformation is not a magic bullet, but a dynamic ability in which we have to keep up with both market and environmental forces. It will take efforts and sustained investments to create sustainable resilience, strategic complementarities, and an investment in a proactive learning culture that will be the core of supply chain operations.

4.4 Summary

This chapter indicated that COVID-19 has affected supply chains with logistical delays, inventory shortages and unpredictable demand that exhibited vulnerabilities of supply chain operations and a failure to digitally integrate. The use of AI and IoT, blockchain, and cloud platforms and technology were demonstrated to improve efficiency, visibility, and sustainability associated with digital transformation. Some obstacles, like costly barriers, legacy system integration, and employee opposition, have been mentioned, whereas the main enablers were leadership support, training, and going on a pilot. There were strong correlations between resilience, operational efficiency, and digital adoption via regression analysis. In general, the chapter underlined the significance of technology-based strategies to develop an agile, sustainable and competitive supply chain in the post-pandemic period.

Chapter 5: Conclusion and Recommendations

5.1 Differences Between the Literature Review and Research Findings

The regression analysis has contributed to the study that there was a statistically significant relationship between improved efficiency and decisions on digital adoption ($p = 0.002$), preparedness and resilience ($p = 0.0009$). On the other hand, the review of published studies demonstrated that emphasised that AI increased the accuracy of demand forecasts, IoT made it possible to monitor the location of inventory and logistics in real-time, and Blockchain helps to get more information about the suppliers. On the other hand, the review has also demonstrated that supplier concentration is a critical factor considered in the use of digitalisation in the supply chain. In contrast, the literature review has highlighted that AI-driven demand forecasting as well as smart tracking systems usually lead to effective and seamless operations within organisations, due to the involvement of emerging technologies and their abilities to perform in a more efficient manner. Altogether, it has also attributed digital twins and predictive analytics to the shortening of lead times and improvement of risk response. Therefore, organisations that had clear roadmaps with strong leadership tendencies usually gain the ability to neutralise barriers such as old systems, skills and cultural challenges with increased capacity.

5.2 Similarities between the Literature Review and Research Findings

The primary research has concluded that digital transformation is highly valuable towards improving the resilience and efficiency of global supply chains, especially due to pandemic-related disturbances. The survey of 53 responses has highlighted that there were high scores on the perception of the digital tools on the enhancement of decision-making, transparency, and operational performance. Besides, the means of descriptive results have also indicated high scores (more than 3.7) in important variables of transparency, inventory tracking, and strategic alignment.

From these perspectives, it can be established that these qualitative findings using NVivo and thematic analysis have resonated and enriched the outcomes concerning the role of digital transformation in global supply chain practices, especially in the post-pandemic era. The demonstration of its core original idea of digital transformation no longer being a choice but a strategic imperative serves to legitimise the general research of the basic study. Nowadays, companies that holistically implemented those technologies have a better record in terms of the recovery process after a crisis, cost management, and sustainability, which has been supported through both primary qualitative and quantitative findings.

The interview findings have demonstrated that the use of digital technologies, such as digital twin, aids in delivering supply chain scenario simulation to improve risk identification and mitigation on a timely basis. Similarly, the review of published literature has proven that digitisation provides supply chains with the ability to be agile, transparent, and intelligent to survive the volatile global environment, as well as to adapt and lead from a global perspective.

5.3 Overall Summary and Implications of the Research

Both the primary quantitative and qualitative research findings have contributed to creating the pathway to achieve the first objective, regarding the impact of the pandemic on global supply chain operations. Manager 1 reported to the first question that the lack of visibility of real-time data is a key cause behind the disruption, whereas Manager 3 referred to the sequence of delays due to supplier dependence in global supply chain operations. Such disturbances could also be found in the survey, as a high degree of agreement indicated that the largest number of organisations are only relatively ready. From this aspect, it has been highlighted that there are worries regarding future disruptions, as confirmed by descriptive statistics (mean = 4.52). This collective evidence has proven that COVID-19 revealed structural weak points; for this reason, modernisation and resilience-building in global supply chains are direly needed in the post-pandemic era.

The interview questions Q2 and Q3 are significantly aligned second objective, as these findings have indicated that the AI, IoT, and Blockchain are used to enhance major elements of supply chain operations. Concerning this, Manager 1 told the story of how AI-aided forecasting decreased lead times, whereas Manager 3 opined that IoT sensors enhanced inventory tracking capability. Apart from this, the results of a survey demonstrated a high degree of congruence with those advantages, with the help of descriptive statistics (mean score 3.76-3.89). Regression analysis has also shown that there is a highly statistically significant positive correlation ($p = 0.002$) between digital adoption and operational efficiency. Other enhancements in sustainability have also been explained, such as carbon monitoring, waste reduction, which illustrate that digital tools assist the performance as well as the environment-related objectives.

The third objective has been achieved by harnessing both primary sources of data, more so Interview Q4, which had probed the barriers and enablers. In regard to that, Manager 5 mentioned the cultural resistance, but Manager 2 suggested that legacy systems posed significant integration problems. Besides, Manager 3 mentioned financial constraints that would slow down progress in the beginning. Nevertheless, the enabling activities of good leadership (Manager 1), pilot tests (Manager 3), and cooperation with cloud vendors (Manager 2) have also been identified as the major motivators. The results of the survey are consistent, meaning that the level of digital preparedness is moderate, where an average achievement of the training being 3.79. The results have indicated that even though digital tools are very promising, effective use requires people, mentality, and strategic vision, as well.

The fourth milestone has been fulfilled by focusing on Interview question Q5, which explicitly gave out practical suggestions. In this perspective, Manager 1 suggested one would write a structured roadmap and discussing pilot tests of digital solutions to gain competitive success from a broader perspective. On the other hand, Managers 2 and 3 recommended focusing on the integrity of data to get quality analytics and training of personnel, respectively. The results of the survey have presented a realistic and actionable way

forward, backed by an affirmative assessment of tools effectiveness of digital tools. They can be combined to give organisations a blueprint to operate modernised processes with greater resilience and to benefit from supply chain balanced and secure operations.

In regard to that, a list of recommendations concerning the role of digital transformation in the post-pandemic is mentioned below.

- ***Development of a strategic roadmap for digitalisation***

Organisations are advised to pursue a phased digital roadmap emphasising operational gaps where there is a need, mainly in forecasting, tracking, or inventory management. This roadmap should ensure that the digital initiatives are in line with long-term goals. Besides, the results of the survey and regression showed that efficiency gains only emerged in response to the tactical deployment of digital tools and not in isolation and non-integration of the tool.

- ***Workforce training and prioritising change management***

In order to address the internal resistance and fill capability gaps, companies have to create obligatory digital upskilling and cross-level training programs. Themes and interviews coded in NVivo have revealed that employees were often not certain and did not understand requirements due to a lack of digital knowledge and excellence. Integration of such efforts with the organisational culture will enhance system uptake and realisation of all benefits associated with digital solutions.

- ***Enhancement of data governance and system integration***

Companies need to update old systems and use interoperable real-time digital platforms. Concerning this, the NVivo themes of system indicated that the AI and IoT tools perform to increase supply chain resilience, as they boost efficiency of overall operations and activities globally, specifically in the post-pandemic era. Businesses need to focus on the free flow of connectivity between platforms, allowing them to have precise forecasts, quicker decision-making and entire supply chain visibility.

- ***Boosting investment in emerging technologies***

Organisations ought to select the digital technology that facilitates both the performance of the operations and the environmental targets. The expense reductions in waste discourse, altogether with the monitoring of emissions, have been demonstrated in interviews as well as NVivo data via tools such as IoT and AI. Companies have to invest in platforms that promote sustainable objectives, but at the same time increase their resilience, making them able to respond to stakeholder and regulatory requirements.

- ***Utilisation of performance KPIs and continuous monitoring***

In order to properly gauge the effects of transformation, businesses need to settle down and track important digital KPIs, including time of leadership, demand fidelity, and carbon emissions. In regard to that, the NVivo observations and interview results have proved that ongoing assessment creates

accountability and enables on-time changes. Reviews and performance dashboards will keep long-term digital performance focused.

Research Limitations

This research has been restrained by the small sample size, which has been employed in the semi-structured interviews, thus limiting the diversity of opinions sought in the context of the role of digital transformation in the post-pandemic period. Moreover, it has also failed to involve secondary data sources like industry reports or case studies, which would have added more depth to analytics. These weaknesses have hindered the applicability and situational depth of the results in the larger context of supply chains and across industry classifications.

Future Scope

The study has identified avenues where there is a need to conduct further research to explore upcoming technological advancements with a lens on both secondary and primary data. Secondary data, including industry reports and benchmarking studies, can also be added to future research to enhance contextual data in the same or a relevant field of research. This is possible by increasing the sample size to other industries and regions worldwide, which would enhance generalisability. Other possibilities may include investigating new technologies such as robotics or digital twins, and researchers may consider a longitudinal study to measure the effects of digital transformation on supply chain resilience and sustainability on a long-term basis.

Reference

Adeoye-Olatunde, O.A. and Olenik, N.L. (2021). Research and Scholarly Methods: Semi-Structured Interviews. *Journal of the American College of Clinical Pharmacy*, [online] 4(10), pp.1358–1367.

Adeusi, K.B., Adegbola, A.E., Amajuoyi, P., Adegbola, M.D. and Benjamin, L.B., (2024). The potential of IoT to transform supply chain management through enhanced connectivity and real-time data. *World journal of advanced engineering technology and sciences*, *12*(1), pp.145-151.

Aljohani, A. (2023). Predictive Analytics and Machine Learning for Real-Time Supply Chain Risk Mitigation and Agility. *Sustainability*, [online] 15(20), p.15088.

Allsop, D., Chelladurai, J., Kimball, E., Marks, L. and Hendricks, J. (2022). Qualitative Methods with Nvivo Software: a Practical Guide for Analyzing Qualitative. *Qualitative Methods with Nvivo software: a Practical Guide for Analyzing Qualitative Data*, 4(2), pp.142–159.

Anica-Popa, L.E., Vrîncianu, M. and PETRICĂ, I.M., (2023). AI–powered Business Services in the Hyperautomation Era. In Proceedings of the International Conference on Business Excellence (Vol. 17, No. 1, pp. 1036-1050). *Sciendo*.

Ayoola, V.B., Osam-nunoo, G.E.O.R.G.E., Umeaku, C.H.I.M.A. and Awotiwon, B.O., (2024). IoT-driven Smart Warehouses with Computer Vision for Enhancing Inventory Accuracy and Reducing Discrepancies in Automated Systems.

Balkhi, B., Alshahrani, A. and Khan, A. (2022). Just-in-Time Approach in Healthcare Inventory Management: Does It Really Work? *Saudi Pharmaceutical Journal*, [online] 30(12), pp.1830–1835.

Bari, M.H. and Ara, A. (2025). The Impact of Machine Learning on Prescriptive Analytics for Optimized Business Decision-Making. *SSRN Electronic Journal*.

Bas, T.G., Astudillo, P., Rojo, D. and Trigo, A., (2023). Opinions related to the potential application of artificial intelligence (AI) by the responsible in charge of the administrative

management related to the logistics and supply chain of medical stock in health centers in north of Chile. *International Journal of Environmental Research and Public Health,* 20(6), p.4839.

Bayramova, A., Edwards, D.J. and Roberts, C. (2021). The Role of Blockchain Technology in Augmenting Supply Chain Resilience to Cybercrime. *Buildings*, 11(7), p.283.

Beamish, P.W. and Chakravarty, D. (2021). Using the Resource-Based View in Multinational Enterprise Research. *Journal of Management*, 47(7), p.014920632199557.

Bednarski, L. (2023). Geopolitical Disruptions in Global Supply chains: a state-of-the-art Literature Review. *Production Planning & Control*, [online] 36(4), pp.1–27.

Beninger, P., Caubel, P., Sharma, L., Pajovich, G. and Boyd, P., (2022). Effects of the Covid-19 pandemic on pharmacovigilance strategy, systems, and processes of large, medium, and small companies: An industry survey. *Clinical Therapeutics*, 44(9), pp.1225-1236.

Bennett, E.E. and McWhorter, R.R. (2021). Virtual HRD's Role in Crisis and the Post Covid-19 Professional Lifeworld: Accelerating Skills for Digital Transformation. *Advances in Developing Human Resources*, 23(1), pp.5–25.

Bille, A. and Hendriksen, C. (2022). Let us get contextual: critical realist case studies in supply chain management. *Supply Chain Management: An International Journal*.

Bisht, N.S., Trusson, C., Siwale, J. and Ravishankar, M.N. (2021). Enhanced job satisfaction under tighter technological control: The paradoxical outcomes of digitalisation. *New Technology, Work and Employment*, 38(2). doi:https://doi.org/10.1111/ntwe.12222.

Bown, C.P. and Bollyky, T.J., (2022). How COVID-19 vaccine supply chains emerged in the midst of a pandemic. *The World Economy,* 45(2), pp.468-522.

Chakraborty, A. and Mateen, A., (2025). Guest editorial: Special issue on "Global supply chain transformation using digital technologies in the post-pandemic era". *Journal of Global Operations and Strategic Sourcing*, *18*(1), pp.1-4.

Chari, A., Niedenzu, D., Despeisse, M., Machado, C.G., Azevedo, J.D., Boavida-Dias, R. and Johansson, B. (2022). Dynamic capabilities for circular manufacturing supply chains—Exploring the role of Industry 4.0 and resilience. *Business Strategy and the Environment*, 31(5), pp.2500–2517.

Chauhan, M. and Sahoo, D.R., (2024). Towards a greener tomorrow: Exploring the potential of AI, blockchain, and IoT in sustainable development. *Nature Environment and Pollution Technology*, *23*(2), pp.1105-1113.

Chen, H., Wang, Z. and Zhang, M., (2024). Mechanism Study on Innovative Influences of AI and Blockchain on Supply Chain Logistics: Case Study of JD and Alibaba. Advances in Economics, *Management and Political Sciences*, 109, pp.94-100.

Chen, Y. and Biswas, M.I. (2021). Turning Crisis into Opportunities: How a Firm Can Enrich Its Business Operations Using Artificial Intelligence and Big Data during COVID-19. *Sustainability*, 13(22), p.12656.

Cho, Y.S. and Linderman, K. (2020). Resource-Based Product and Process Innovation Model: Theory Development and Empirical Validation. *Sustainability*, [online] 12(3), p.913.

Choksy, U.S., Ayaz, M., Al-Tabbaa, O. and Parast, M. (2022). Supplier resilience under the COVID-19 crisis in apparel global value chain (GVC): The role of GVC governance and supplier's upgrading. *Journal of Business Research*, 150, pp.249–267.

Dura, B.S., Nadeem, S.P., Garza-Reyes, J.A., Alemu, A.E., Tabar, B.R., Zapata, D.H. and Kreie, A. (2025). The role of technology in developing resilient supply chains: a systematic literature review during the COVID-19 pandemic and the disruptions of economic sanctions. *Journal of Humanitarian Logistics and Supply Chain Management*.

Frederico, G.F. (2021). Towards a Supply Chain 4.0 on the post-COVID-19 pandemic: a conceptual and strategic discussion for more resilient supply chains. *Rajagiri Management Journal*, ahead-of-print(ahead-of-print).

Ghobakhloo, M., Iranmanesh, M., Foroughi, B., Tseng, M., Nikbin, D. and Khanfar, A.A. (2023). Industry 4.0 digital transformation and opportunities for supply chain resilience: A comprehensive review and a strategic roadmap. *Production Planning & Control*, 36(1), pp.1–31.

Ghorbanian, A., Aiello, B. and Staples, J. (2021). Under-Representation of Transgender Identities in Research: The Limitations of Traditional Quantitative Survey Data. *Transgender Health*, 7(3).

Goswami, S.S., Mondal, S., Sarkar, S., Gupta, K.K., Sahoo, S.K. and Halder, R. (2024). Artificial Intelligence Enabled Supply Chain Management: Unlocking New Opportunities and Challenges. *Artificial Intelligence and Applications*, 3(1).

Goyal, M. and Deshwal, P. (2022). Online post-purchase customer experience: a qualitative study using NVivo software. *Quality & Quantity*, 57.

Guergov, S. and Radwan, N. (2021). Blockchain Convergence: Analysis of Issues Affecting IoT, AI and Blockchain. *International Journal of Computations, Information and Manufacturing (IJCIM)*, 1(1).

Hammerer, K., 2024. Visibility in multi-tier supply chains: A study on barriers, challenges and solutions.

Handema, M., Lungu, J., Chabala, M. and Shikaputo, C. (2023). Conceptualising the Philosophical Underpinning of the Study: A Practical Perspective. *Open Journal of Philosophy*, [online] 13(02), pp.257–268.

Hossain, M.I., Subrata Talapatra, Saha, P. and Belal, H.M. (2024). From Theory to Practice: Leveraging Digital Twin Technologies and Supply Chain Disruption Mitigation Strategies for Enhanced Supply Chain Resilience with Strategic Fit in Focus. *Global Journal of Flexible Systems Management*.

Huang, K., Wang, J. and Zhang, J., (2023). Automotive supply chain disruption risk management: a visualization analysis based on bibliometric. *Processes*, 11(3), p.710.

Imran, H., (2024). interpretivism critical realism and mixed methods in inter-disciplinary research—management and information systems. *Valley International Journal Digital Library*, pp.5953-5962.

Jafari, H., Ghaderi, H., Malik, M. and Bernardes, E. (2022). The effects of supply chain flexibility on customer responsiveness: the moderating role of innovation orientation. *Production Planning & Control*, [online] 34(16), pp.1–19.

Junjie, M. and Yingxin, M. (2022). The Discussions of Positivism and Interpretivism. ERIC, Eric.

Kandhare, P., Kurlekar, M., Deshpande, T. and Pawar, A. (2025). A Review on Revolutionizing Healthcare Technologies with AI and ML Applications in Pharmaceutical Sciences. *Drugs and Drug Candidates*, [online] 4(1), p.9.

Khan, A.A., Laghari, A.A., Li, P., Dootio, M.A. and Karim, S., (2023). The collaborative role of blockchain, artificial intelligence, and industrial internet of things in digitalization of small and medium-size enterprises. *Scientific Reports*, *13*(1), p.1656.

Kircher, R. and Zipp, L. (2022). *Research methods in language attitudes*. Cambridge, United Kingdom; New York, Ny: Cambridge University Press, pp.99–113.

Klug, F., (2022). Modelling oscillations in the supply chain: the case of a just-in-sequence supply process from the automotive industry. *Journal of Business Economics*, 92(1), pp.85-113.

Kouam, A.W.F. (2025). Toward Digital Transformation: Insights into Chinese Cross-Border E-Commerce SMEs During the COVID-19 Pandemic and the Post-Pandemic Era. *Sage Open*, 15(1).

Kuo, S., Ou, H.T. and Wang, C.J., (2021). Managing medication supply chains: Lessons learned from Taiwan during the COVID-19 pandemic and preparedness planning for the future. *Journal of the American Pharmacists Association*, 61(1), pp. e12-e15.

Lim, W.M. (2024). What Is Qualitative research? an Overview and Guidelines. *Australasian Marketing Journal (AMJ)*, [online] 33(2), pp.1–31.

Lin, Y., Xue, B. and Wang, C., (2021). Concentration and diversification: components suppliers' strategy in utilising external knowledge. *Innovation*, 23(4), pp.489-506.

Liu, J., Ali, D.A. and Liu, Z., 2025. Challenges of Localization Requirements for Medical Device Manufacturers and Strategic Responses. *European Journal of Business, Economics & Management,* 1(1), pp.59-68.

Lu, Y., Zhang, Q., Wang, L. and Zhang, Y., (2021), December. The Business Competitiveness and Future Proposing of Alibaba Group. In 2021 3rd International Conference on Economic Management and Cultural Industry (ICEMCI 2021) (pp. 359-368). *Atlantis Press.*

Ma, J.Y., Shi, L. and Kang, T.W., (2022). The effect of digital transformation on the pharmaceutical sustainable supply chain performance: The mediating role of information sharing and traceability using structural equation modelling. *Sustainability*, 15(1), p.649.

Maeno, K., Tokito, S. and Kagawa, S., (2022). CO2 mitigation through global supply chain restructuring. *Energy Economics*, 105, p.105768.

Magableh, G.M., (2021). Supply chains and the COVID-19 pandemic: A comprehensive framework. *European Management Review*, *18*(3), pp.363-382.

Milewski, D., (2022). Managerial and economical aspects of the just-in-time system "lean management in the time of pandemic". *Sustainability*, 14(3), p.1204.

Mohsen, B.M., (2023). Developments of digital technologies related to supply chain management. *Procedia Computer Science*, *220*, pp.788-795.

Monsone, C., (2021). Holistic approach to smart factory. In Artificial Intelligence for Knowledge Management: 8th IFIP WG 12.6 International Workshop, AI4KM 2021, Held at IJCAI 2020, Yokohama, Japan, January 7–8, 2021, Revised Selected Papers 8 (pp. 160-176). *Springer International Publishing.*

Nkuna, J., Vermeulen, A. and Pretorius, J.H.C., (2023). The Integration of Toyota Production System (TPS) and Lean Operations. In Proceedings of the second Australian international

conference on industrial engineering and operations management, Melbourne, Australia, November 14-16 (Vol. 60).

Odumbo, O., Asorose, E., Oluwagbade, E. and Alemede, V., (2024). Reengineering sustainable pharmaceutical supply chains to improve therapeutic equity in US underserved health regions. *Int J Eng Technol Res Manag*, 8(6), p.208.

Ogbuagu, O.O., Mbata, A.O., Balogun, O.D., Oladapo, O., Ojo, O.O. and Muonde, M., (2023). Quality assurance in pharmaceutical manufacturing: Bridging the gap between regulations, supply chain, and innovations. *International Journal of Multidisciplinary Research and Growth Evaluation,* 4(1), pp.823-831.

Osunkanmibi, A.A., Adeoye, Y., Ogunyankinnu, T., Onotole, E.F., Salawudeen, M.D., Abubakar, M.A. and Bello, A.D., (2025). Cybersecurity and Data Protection in Supply Chains: AI's Role in Protecting Sensitive Financial Data across Supply Chains.

Panya, K.O. and Nyarwath, O., (2022). Demystifying philosophies and paradigms underpinning scientific research. *The Strategic Journal of Business & Change Management*, *9*(4), pp.1367-1382.

Pathak, V., Rahul Jashvantbhai Pandya, Bhatia, V. and Onel Alcaraz Lopez (2023). Qualitative Survey on Artificial Intelligence Integrated Blockchain Approach for 6G and Beyond. *IEEE Access*, 11, pp.105935–105981.

Pilarska, J. (2021). The Constructivist Paradigm and Phenomenological Qualitative Research Design. *Research Paradigm Considerations for Emerging Scholars*, 1, pp.64–83.

Pilati, F., Tronconi, R., Nollo, G., Heragu, S.S. and Zerzer, F., (2021). Digital twin of COVID-19 mass vaccination centers. *Sustainability*, 13(13), p.7396.

Qi, W., (2022). Path to Enhance the International Competitiveness of Cross-Border E-Commerce Logistics Enterprises-Research Based on AHP Analysis Method. *International Journal of Frontiers in Sociology,* 4(8).

Rahman, M.D., (2024). E-commerce Evolution: A Strategic Analysis of Alibaba's Business Ecosystem. *Available at SSRN 5109165.*

Reynolds, S., (2024). Adapting to Technological Change: A Qualitative Investigation of Digital Transformation in Supply Chain Operations.

Roblek, V., Meško, M., Pušavec, F. and Likar, B. (2021). The Role and Meaning of the Digital Transformation As a Disruptive Innovation on Small and Medium Manufacturing Enterprises. *Frontiers in Psychology*, 12.

Salim, L.H. and Abdillah, L., (2022). Implementasi Enterprise Resource Planning (ERP) Terhadap Perkembangan UMKM (Studi Kasus Mitra Motor Toyota). KALBISIANA Jurnal Sains, B*isnis dan Teknologi*, 8(2), pp.2058-2075.

Saunders, M., Lewis, P.H.I.L.I.P. and Thornhill, A.D.R.I.A.N., (2007). Research methods. Business Students 4th edition Pearson Education Limited, England, 6(3), pp.1-268.

Saunders, M.N.K., Lewis, P. and Thornhill, A. (2019). *Research Methods for Business Students. 8th Edition, Pearson, New York. - References - Scientific Research Publishing*. [online] www.scirp.org. Available at: https://www.scirp.org/reference/referencespapers?referenceid=2907709 [Accessed 04 June 2025]

Schleper, M.C., Gold, S., Trautrims, A. and Baldock, D. (2021). Pandemic-induced Knowledge Gaps in Operations and Supply Chain management: COVID-19's Impacts on Retailing. *International Journal of Operations & Production Management*, 41(3), pp.193–205.

Schroeder, M. and Lodemann, S., (2021). A systematic investigation of the integration of machine learning into supply chain risk management. *Logistics*, 5(3), p.62.

Scott, G.Y., Aborode, A.T., Adesola, R.O., Khan, M., Elebesunu, E.E., Oluwaseun, A.A., Ahmad, M., Nibokun, E.O., Kwaku, S.D., Bakre, A.A., Chukwu, P.N., Olapade, Z., Osu, A.I., Onifade, I.A., Ogundijo, O.A., Olaoye, J., Bakare-Abidola, T., Fakorede, S. and Olapade, S. (2025). Enhancing Vaccine Quality and Accessibility: Strategies for Efficient Storage and Distribution in Resource-Constrained Environment. *Outbreak Management and Response*, 1(1).

Shen, Z.M. and Sun, Y., (2023). S trengthening supply chain resilience during COVID-19: A case study of JD. com. *Journal of operations management*, *69*(3), pp.359-383.

Silkoset, R. and Nygaard, A. (2025). Leveraging Blockchain and Smart Contracts to Combat Greenwashing in Sustainable Development. *Sustainable Development*.

Siota, J. and Prats, M.J., (2021). Open Innovation How Corporate Giants Can Better Collaborate with Deep-Tech Start-ups. The Case of East and Southeast Asia.

Sodhi, M.S., Seyedghorban, Z., Tahernejad, H. and Samson, D. (2022). Why emerging supply chain technologies initially disappoint: Blockchain, IoT, and AI. *Production and Operations Management*, 31(6).

Sodhi, M.S., Tang, C.S. and Willenson, E.T. (2021). Research opportunities in preparing supply chains of essential goods for future pandemics. *International Journal of Production Research*, [online] 61(8), pp.1–16.

Statista (2024). *Global digital transformation spending 2023*. [online] Statista. Available at: https://www.statista.com/statistics/870924/worldwide-digital-transformation-market-size/.

Stroumpoulis, A. and Kopanaki, E. (2022). Theoretical perspectives on sustainable supply chain management and digital transformation: A literature review and a conceptual framework. *Sustainability*, [online] 14(8), p.4862.

Stroumpoulis, A. and Kopanaki, E., (2022). Theoretical perspectives on sustainable supply chain management and digital transformation: A literature review and a conceptual framework. *Sustainability*, *14*(8), p.4862.

Tagde, P., Tagde, S., Bhattacharya, T., Tagde, P., Chopra, H., Akter, R., Kaushik, D. and Rahman, Md.H. (2021). Blockchain and artificial intelligence technology in e-Health. *Environmental Science and Pollution Research*, [online] 28(38), pp.52810–52831.

Tiwari, M.K., Bidanda, B., Geunes, J., Fernandes, K. and Dolgui, A. (2024). Supply chain digitisation and management. *International Journal of Production Research*, [online] 62(8), pp.2918–2926.

Trabucco, M. and De Giovanni, P., (2021). Achieving resilience and business sustainability during COVID-19: The role of lean supply chain practices and digitalization. *Sustainability*, 13(22), p.12369.

Varriale, V., Cammarano, A., Michelino, F. and Caputo, M., (2021). Sustainable supply chains with blockchain, IoT and RFID: A simulation on order management. *Sustainability*, 13(11), p.6372.

Vlahou, A., Hallinan, D., Apweiler, R., Argiles, A., Beige, J., Benigni, A., Bischoff, R., Black, P.C., Boehm, F., Céraline, J., Chrousos, G.P., Delles, C., Evenepoel, P., Fridolin, I., Glorieux, G., van Gool, A.J., Heidegger, I., Ioannidis, J.P.A., Jankowski, J. and Jankowski, V. (2021). Data Sharing Under the General Data Protection Regulation. *Hypertension*, [online] 77(4), pp.1029–1035.

Wang, W. and Liu, C. (2023). Dynamic Capability Theory Based Study on Performance of Intelligent Manufacturing Enterprise under RFID Influence. *Electronics*, 12(6), p.1374.

Wartini, S., Prananta, W., Febriatmoko, B. and Putri, P.I. (2024). Theory of Resource-Based View (RBV): Integrated Framework of Distinctive Capability in University Performance. *Media Ekonomi dan Manajemen*, [online] 39(2), pp.334–349.

Wells, N., Nguyen, V.K. and Harbarth, S., (2024). A pharmaceutical policy accident: collision of shareholder capitalism and Chinese state capitalism driving the shortage of an essential antibiotic. *Journal of Pharmaceutical Policy and Practice,* 17(1), p.2430441.

Wong, W.P., Saw, P.S., Jomthanachai, S., Wang, L.S., Ong, H.F. and Lim, C.P., (2023). Digitalization enhancement in the pharmaceutical supply network using a supply chain risk management approach. *Scientific Reports,* 13(1), p.22287.

Xu, Z. and Hou, J. (2024). CEO overseas experience, dynamic capabilities and corporate digital transformation: An imprinting theory perspective. *Humanities & social sciences communications*, 11(1).

Yang, S., Cao, N. and Yu, B. (2023). Wear debris measurement in lubricating oil based on inductive method: A review. *Measurement and Control*, 56(7-8), pp.1422–1435.

Zampou, E., Mourtos, I., Pramatari, K. and Seidel, S., (2022). A design theory for energy and carbon management systems in the supply chain. *Journal of the Association for Information Systems*, *23*(1), pp.329-371.

Zhang, A., (2024). Research on enterprise digital transformation: A case study of Alibaba. In SHS Web of Conferences (Vol. 208, p. 01014). *EDP Sciences.*

Zhang, H.-N. (2023). Coupling System Dynamics Model of Cross Border Logistics and Ecological Environment Based on the Sustainable Perspective of Global Value Chain. *Sustainability*, [online] 15(17), p.13099.

Zhu, X. and Wu, Y.J. (2022). How Does Supply Chain Resilience Affect Supply Chain Performance? The Mediating Effect of Sustainability. *Sustainability*, 14(21), p.14626.

Appendix

Interview Questions and Reponses

1: How did the COVID-19 pandemic affect your supply chain operations, and what were the most significant challenges faced?	
Manager	**Response**
Manager 1	COVID-19 caused unprecedented disruption in global logistics. Factory shutdowns and port delays significantly extended lead times. We faced severe inventory shortages, particularly for critical components sourced from Asia. Demand unpredictability was another major challenge, as consumer behaviour shifted rapidly. The lack of real-time data visibility across suppliers worsened the situation. We had to increase safety stock and diversify suppliers to mitigate risks.
Manager 2	The pandemic led to major supplier delays and cost escalations. With air freight capacity reduced and sea freight congested, transportation costs doubled. Limited visibility made it difficult to forecast demand accurately. Workforce restrictions and social distancing requirements slowed warehouse operations. Our biggest challenge was balancing cost efficiency while maintaining service levels.
Manager 3	We struggled with raw material shortages, particularly from overseas suppliers. The closure of manufacturing hubs caused cascading delays across our network. Demand spikes for essential goods added to the pressure, while non-essential product lines faced a sharp decline. The lack of integration between our suppliers and logistics providers made coordination harder.

Manager 4	COVID-19 disrupted every stage of our supply chain. Procurement faced long delays, logistics costs surged, and sudden changes in customer demand created significant planning issues. Manual reporting processes slowed our response times. We realised that we lacked end-to-end visibility, making it difficult to manage supplier performance or identify risks early.
Manager 5	The pandemic exposed vulnerabilities in our global supplier base. Key suppliers in heavily affected regions were unable to deliver, forcing us to find alternatives at higher costs. Logistics bottlenecks delayed shipments for weeks. Inventory inaccuracies compounded the problem.

Q2: In what ways has digital transformation improved operational efficiency and visibility within your supply chain?	
Manager	**Response**
Manager 1	Digital transformation allowed us to automate demand forecasting and inventory management. AI-driven tools predict future demand with higher accuracy, reducing overstock and stockouts. Real-time shipment tracking has eliminated blind spots in transportation. Our warehouses now use automated picking systems, which have improved efficiency and reduced errors. This level of visibility has empowered faster decision-making, ultimately reducing lead times and operational costs significantly.

Manager 2	The use of cloud-based platforms gave us real-time visibility of our entire supply chain, from suppliers to customers. Predictive analytics helped us anticipate disruptions and reroute shipments proactively. Automation of repetitive tasks like order processing freed up resources for strategic initiatives.
Manager 3	We implemented IoT sensors for monitoring inventory and equipment status. This technology reduced downtime and enhanced supply accuracy. Blockchain-based supplier tracking has improved transparency and reduced disputes over delivery timelines. Digital dashboards now allow our teams to monitor key performance indicators instantly, speeding up response times during disruptions.
Manager 4	AI-powered demand planning tools have optimised procurement schedules and minimised excess stock. Automation in our warehouses has cut operational costs by 15%. Enhanced visibility across suppliers using integrated platforms allows for better coordination, reducing delays and improving customer service. Digital transformation has turned our supply chain from reactive to proactive.
Manager 5	We now leverage digital twins to simulate supply chain scenarios and mitigate risks in advance. Machine learning algorithms have reduced forecasting errors by 20%. End-to-end visibility has improved supplier compliance and reduced inefficiencies. This data-driven approach has significantly strengthened our operational resilience and efficiency.

Q3: How can digital tools help in building a sustainable and environmentally responsible supply chain?

Manager	Response
Manager 1	IoT sensors track energy usage across our warehouses, helping us identify ways to reduce power consumption. Digital route optimisation tools minimise fuel usage and emissions in transportation. Blockchain ensures that our suppliers meet ethical and sustainability standards, which strengthens our compliance reporting.
Manager 2	Digital tools provide real-time data on carbon emissions across our supply chain. We use this information to optimise shipping routes and consolidate loads. Additionally, AI-based demand forecasting reduces waste by ensuring we only produce what is needed, contributing to sustainable operations.
Manager 3	We implemented sustainability dashboards to track environmental metrics, such as emissions and resource consumption. By integrating these into our ERP systems, we can identify high-impact areas for improvement. Our blockchain solution also verifies the sustainability credentials of our suppliers, ensuring responsible sourcing.
Manager 4	Through the use of big data analytics, we analyse environmental risks and develop strategies to mitigate them. Digital collaboration platforms also allow us to work with partners on sustainability initiatives. This approach has helped us meet government regulations while reducing operational waste.
Manager 5	AI and machine learning have enabled us to predict excess inventory and repurpose it before it becomes waste. Our digital compliance tools ensure every supplier meets our sustainability benchmarks, creating a greener and more ethical supply chain.

Q4: What are the main barriers and key enablers your organisation encountered while implementing digital transformation in the supply chain?	
Manager	**Response**
Manager 1	The biggest barrier was employee resistance to new technology. Many were comfortable with manual processes. Strong leadership support and targeted training sessions were key enablers in driving adoption.
Manager 2	Integration with legacy systems was the toughest challenge. However, partnering with experienced technology vendors and adopting scalable cloud solutions enabled us to overcome this barrier.
Manager 3	Budget constraints initially delayed the project. The turning point was demonstrating clear ROI through pilot programs, which convinced stakeholders to invest in full-scale digital adoption.
Manager 4	Data quality was a major barrier. We tackled it by implementing robust data governance policies and using automated data-cleansing tools, which became a strong enabler for success.
Manager 5	Cultural change was our primary challenge. We overcame it through continuous communication, change management workshops, and involving employees early in the transformation process.

Q5: What practical recommendations would you give to organisations looking to modernise their supply chains using digital tools to enhance resilience and security?	
Manager	**Response**
Manager 1	Start with a clear roadmap. Identify critical pain points and pilot digital solutions before scaling. This reduces risks and builds confidence among stakeholders.
Manager 2	Invest in high-quality data management. Reliable data is the backbone of effective digital transformation and predictive decision-making.
Manager 3	Focus on employee training and change management. Digital tools are only effective if your workforce understands how to use them efficiently.
Manager 4	Partner with technology providers who offer scalable, secure, and customizable solutions. This ensures smooth integration and long-term adaptability.
Manager 5	Measure success with clear KPIs. Track cost savings, lead-time reductions, and sustainability metrics to ensure that digital transformation delivers tangible value.