

Mapping Digital Technologies in Supply Chain Sub-Functions

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Submitted by: Tayade Ashutosh

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First Supervisor: Prof. Dr.- Brunotte René

Second Supervisor: Prof. Dr. Behrmann Malte

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Abstract:

This thesis investigates the integration of digital technologies in supply chain management, focusing on identifying critical technologies, assessing their impact on efficiency, and exploring strategic implementation challenges. It analyzes the role of IoT, AI, blockchain, and analytics in enhancing supply chain sub-functions such as procurement, logistics, and inventory management. The study evaluates how these technologies improve competitiveness, resilience, and operational efficiency. It addresses strategic considerations for technology adoption, including alignment with business goals and cybersecurity. Challenges like the technical, organizational, and cultural barriers to digital transformation are examined. By providing a roadmap for navigating these complexities, the thesis aims to guide companies through the digital transformation process, highlighting the importance of digitalization in achieving a more agile, transparent, and efficient supply chain and securing a competitive edge in the global market.

Table of Contents

1	Introduction	1
1.1	Supply Chain Management	1
1.2	Digitalization in Supply Chain Management.....	2
1.3	Problem Discussion and Research Gap	3
1.4	Research Question.....	4
1.5	Research Approach.....	4
2	Literature Review	6
2.1	Supply Chain Management	6
2.2	Review of Key Digital Technologies	10
2.3	Impact Digital Technologies in Supply Chain Sub-functions.....	14
2.4	Strategic Considerations and Adoption Challenges	15
2.5	Performance parameters.....	18
3	Case study analysis	22
3.1	Zara.....	22
3.2	PepsiCo.....	26
3.3	Ford.....	30
3.4	Samsung	32
4	Survey and interview findings.....	34
4.1	Theme 1 - Key digital technology.....	36
4.1.1	Technology for increased supply chain complexities	36
4.1.2	Technology in specific supply chain operations	37
4.2	Theme 2 - Impact of Digital Technology	38
4.2.1	Impact of digital technology in supply chain operations.....	39
4.2.2	Level of satisfaction from advancements in technology.....	40
4.3	Theme 3 - Strategic consideration and challenges	41
4.3.1	Current challenges associated with digital technology working ...	41
4.3.2	Key success-factors.....	41
5	Findings analysis.....	43

5.1	Empirical findings for key-performance parameters	43
5.2	Relevancy of digital technology in attaining the conventional supply chain complexities.....	44
5.3	Digital technology and its' application	46
5.4	Answers to research question	47
5.5	Overall analysis	48
6	Key-drivers and challenges associated with digital technological advancements.	49
7	Recommendation	52
8	Conclusion	55
8.1	Future work recommendation	56
9	Survey.....	57
10	References.....	59

List of figures

Figure 1 Key performance parameters for supply chain management (Researcher's finding).....	19
Figure 2 Zara online sales (Statista, 2022).....	23
Figure 3 fast-fashion growth rate (Uberoi, 2018).....	25
Figure 4 PepsiCo revenue (Statista, 2022)	27
Figure 5 AI-driven warehouse management (Caulfield, 2023).....	29
Figure 6 Category-wise revenue (Hwang, 2022).....	32
Figure 7 Digital technology and its' application (researcher's finding)	46
Figure 8 Overall research analysis (Researcher's finding)	48

List of tables

Table 1 Outcome of digitalisation in Zara (Researcher's finding).....	25
Table 2 Outcome of digitalisation in PepsiCo (Researcher's finding).....	29
Table 3 Outcome of digitalisation in Ford (Researcher's finding).....	31
Table 4 Key performance parameters analysis.....	43
Table 5 Impact of digital technology on supply chain complexities (Researcher's finding).....	45

1 Introduction

The chapter emphasises how important it is to do in-depth study on how digital technologies affect supply chain management. While acknowledging the general agreement that digital breakthroughs have the potential to improve supply chain efficiency, it also highlights a substantial knowledge gap on the strategic use and implications of these technologies. The complete application of digital tools for supply chain process optimisation is impeded by this research gap. The chapter lays forth a research programme with the goal of bridging this gap, emphasising the strategic integration of digital technology to enhance supply chain operations. The text highlights the significance of comprehending digital servitization and its impact on supply chains. It argues that a deeper understanding of these facets is necessary to effectively utilise digital innovations to improve supply chain performance and flexibility. The development of more robust, effective, and customer-focused supply chain models in the digital era depends heavily on this investigation.

1.1 Supply Chain Management

There are several definitions of supply chains, but the one I use in my daily life is any activity where raw materials are transformed into completed goods and delivered to customers in time frame, in right quantity, and in precise quality. (Mentzer et al.2001) characterised supply chain management as a breakthrough in the understanding of how the relationship between the movements of capital equipment, labour, supplies, cash, and information affects the success of industrial companies. Transitioning from overseeing discrete tasks to incorporating operations into essential supply chain procedures is necessary for effective supply chain management. Supply chain management is essential to achieving operational excellence, long-term performance, and competitive advantage in business. It has several facets. Increasing productivity, reducing business uncertainty, and encouraging adaptability and inventiveness are essential. Additionally, it enhances cooperation, information exchange, and supply chain integration—all of which boost supply chain efficiency and customer satisfaction. Therefore, to boost business performance, supply chain responsiveness, strategic supplier alliances, and lean and agile supply chain methodologies become essential. (Qrunfleh & Tarafdar, 2013). Additionally, (Kim & Chai, 2016) discusses how business uncertainty affects supply chain integration, considering how dynamic business environments are and how they affect supply chain responsiveness. As a result, it is essential for moderating how information sharing

5 tactics affect flexible supply chains and enhancing the general effectiveness and flexibility of supply chain operations. (Alzoubi & Ramakrishna, 2020).

1.2 Digitalization in Supply Chain Management

The shift of the supply chain business model towards open innovation has been attributed to digital knowledge servitization (Pizzichini et al. 2023).

However, the use of digital technologies in supply chain management has, in recent years, completely changed how companies run, presenting ground breaking prospects and resolving important issues.

The performance, resilience, and sustainability of the supply chain are all significantly impacted by the complex interplay between digital technology and supply chain management. New paradigms, ideas, and models in supply chain management have been inspired by the use of digital technology, such as Industry 4.0 advancements, which has enhanced agility and responsiveness. (Ivanov et al. 2018; Fatorachian & Kazemi, 2020). More synchronised operations result from the fundamental transformation of information sharing among partners brought about by the integration of digital technology inside the supply chain. Real-time data interchange made possible by this digital link allows for speedier adjustments to supply and demand dynamics and enhances overall responsiveness. As a result, the supply chain's structure changes, becoming more resilient and nimbler so that it can adjust to changes in the market more easily. Digital tools minimise duplication, maximise resource allocation, and streamline operations, all of which lead to increased flexibility and efficiency. Additionally, by using data analytics to predict consumer demands and personalise products, this digital evolution strengthens customer orientation and improves customer experience and competitive advantage. (Zouari et al., 2020; Nandi et al., 2021).

Adoption of digital technology affects the structure of the supply chain and enhances flexibility, productivity, and customer orientation. It also improves information flows between supply chain partners and increases the level of integration of the supply chain. (Yang et al., 2021; Hofmann et al., 2019).

Additionally, supply chain management is vital to the global economy since it affects social, environmental, and economic outcomes. (Billah et al., 2023). It is the primary procedure that underpins the activities system of an organisation from upstream to downstream, making it crucial to the efficient operation of the system as a whole (Chansamut, 2023). The importance of supply chain management for

sustainable development is underscored by its role in putting a circular economy and environmental cooperation into practice (Varma, 2023).

Organisations encounter a variety of complex obstacles when integrating digital technology into supply chain subfunctions. New paradigms, ideas, and models in supply chain management have been inspired by disruptive breakthroughs like digitalization and Industry 4.0, but they have also brought new dangers and obstacles (Ivanov et al., 2018). These obstacles consist of inadequate R&D procedures, inadequate infrastructure, low-quality data, a lack of a digital culture, and a lack of partner trust (Ghadge et al., 2020). Additionally, there is a gap in aligning digital strategies with the requirements of supply chain operations as seen by the absence of integration between the implementation of digital strategies and supply chain features (Ho et al., 2023).

Considering how digital technology is used in supply chain management, a deeper understanding of these technologies is required to make effective use of them. While blockchain and Internet of Things (IoT) technologies are known to improve various aspects of supply chain operations, a thorough grasp of how these technologies strategically connect inside sub-functions remains lacking.

Acknowledging the abundance of digital solutions at hand, this study focuses on technology mapping in particular because of its considerable potential to change supply chain dynamics.

1.3 Problem Discussion and Research Gap

The conventional wisdom in most supply chain management literature is (Matt et al., 2015) discussed digital transformation strategies and the desired future business opportunities based on digital technologies. (Zhao et al. 2023) additionally concluded that integrating digital technology into a supply chain might lead to clever management strategies like raising the production system's autonomy and energy efficiency. This highlights the need for additional investigation to identify the precise processes via which digital technologies impact the effectiveness of supply chains.

But (Pichugina 2023) highlighted the need for thorough investigation, development, and study on the subject of digital technologies in supply chains, pointing to a gap in the knowledge and application of this field at the moment.

Also, (Basana et al. 2023) highlighted the need for research to improve the theory of the digital supply chain and make valuable contributions to educating top

management about information technology investment. It also revealed a gap in the current understanding of the impact of key user capability on supply chain digital and flexibility in improving financial performance.

(Pizzichini et al. 2023) helped to integrate the digital servitization concept with the theoretical knowledge-based view of servitization, highlighting the role of this combined perspective in the supply chain's transformation and pointing out the need for more research to fully comprehend the strategic implications and difficulties of digital knowledge servitization in supply chain management.

1.4 Research Question

Q1. What are the key digital technologies relevant for supply chain sub functions?

Q2. How does digital technology impact the supply chain subfunction and efficiency?

Q3. What are the strategic considerations and challenges associated with the implementation of digital technology?

The purpose of the study questions is to analyse how digital technologies affect supply chain management. Specifically, they will identify key technologies, evaluate how they affect productivity and performance of subfunctions, and discuss the problems and concerns of strategic adoption. The research aims to map the technical landscape, analyse the advantages and operational gains brought about by digitalization, and highlight the practical and strategic problems associated with integrating these technologies into supply chains by investigating these topics. This thorough analysis will offer insightful information about how to use digital innovations to improve the competitiveness, resilience, and efficiency of supply chains. It will also provide a roadmap for companies attempting to navigate the challenges of digital transformation in supply chain environments.

1.5 Research Approach

Academic research can take one of three approaches: abductive, deductive, or inductive. A deductive technique is predicated on preexisting theory and is applied to the collected empirical data, whereas inductive research is described as beginning with an empirical investigation with the goal of producing new theory. Combining deductive and inductive research methods is known as abductive research. Although it produces and tests new findings with these preexisting theories and frameworks, it might be predicated on existing theory. (Järvensivu & Törnroos, 2010).

This thesis research employs a mixed-methods approach to investigate the effects of digital technology on supply chain management across various industries by combining quantitative data with qualitative case study analysis. Your study intends to discover the transformative effects of digital technologies on supply chain efficiency, transparency, and overall performance by looking at specific case studies (Zara, PepsiCo, Ford, and Samsung) and integrating empirical findings with a literature review. The supply chain experience holder survey provides additional evidence for the investigation. This all-encompassing approach facilitates a thorough comprehension of the strategic considerations and obstacles associated with the use of digital technology, providing insights into the ways in which digital technologies can improve supply chain operations and support organisational achievement.

2 Literature Review

This thesis's literature study critically analyses the shift in supply chain management (SCM) from traditional to digitally driven, emphasising the importance and effects of incorporating digital technologies into SCM operations. It describes the drawbacks of traditional supply chain management techniques and how supply chain complexity forces businesses to embrace digital innovation. To comprehend the revolutionary implications of technologies like IoT, blockchain, AI, and data analytics on improving supply chain efficiency and agility, key areas including procurement, logistics, and inventory management are investigated. The evaluation also assesses current trends and emphasises the obstacles to digital adoption, laying the foundation for the identification of performance measures and the identification of research gaps.

2.1 Supply Chain Management

The creation of control ideas, the focus on supply chain excellence, and the creation of maturity models to improve SCM processes were all linked to traditional SCM activities (Paulraj et al., 2012). Purchasing, supplier involvement and selection, customer focus, senior management support, relational governance, and interorganizational communication are some of these approaches.

Over the years, a lot of research and development has been done on the advancement of supply chain management, or SCM. The coordination of the transportation and storage of commodities from the point of origin to the point of consumption is where the idea of supply chain management (SCM) first emerged. SCM has expanded over time to include a variety of techniques and ideas, including as system integration, sustainability, corporate social responsibility, and coordinating important business operations to benefit stakeholders and customers (Mukhamedjanova, 2020a).

Contrarily, a wide range of concepts and techniques are now included in supply chain management practices, such as corporate social responsibility, sustainability, system integration, and the synchronisation of important company operations to benefit stakeholders and customers (Croom et al., 2018). While advanced supply chain management (SCM) practices redefine the supply chain by creating new products or processes that benefit multiple stakeholder groups, promote transparency of social sustainability information, and involve NGOs and communities in supply chain decision-making, today's SCM practices are centred

on the health and safety of workers in the supply chain, such as through health and safety monitoring or management systems (Croom et al., 2018).

Because of the changes brought about by globalisation, firms were now required to operate worldwide rather than just locally. This transition brings with it both opportunity and challenges. Businesses now have the chance to create digital business plans and use digital technology to expand their worldwide reach and competitive edge because of globalisation (Mithas et al. 2013).

The problems with conventional supply chain techniques are complex and affect many facets of supply chain management. Conventional supply chain techniques suffer from issues with information exchange, interruption susceptibility, and resilience requirements. These difficulties affect the efficacy and efficiency of supply chain activities, necessitating creative fixes. The requirement to increase supply chain resilience in the face of chaotic external demands and turbulent change poses a challenge to traditional supply chain methodologies (Pettit et al., 2013). The highly interconnected global economy of today makes it unnecessary to rely just on "steady state" circumstances, which calls for the creation of more robust supply chain procedures.

To meet these issues and adjust to the intricacies of the contemporary global economy, supply chain management theory needs to change from previous methods. When taken as a whole, these studies shed insight on the dynamic and intricate world of supply chain management and emphasize the need for creativity and adaptation in this setting.

Ni et Moreover, the adoption of technologies like blockchain in SCM has revolutionized supply chain processes, highlighting the need to adapt to technological advancements to navigate the complexities introduced by globalization (Hasan & Habib, 2022). The utilization of advanced technologies and data-driven approaches, such as demand forecasting models, has become essential in managing the complexities of globalized supply chains (Ni et al., 2022).

The use of digital technologies is now crucial for changing supply chain operations. These technologies provide a number of advantages, including increased managerial effectiveness, better services, technical assistance, and the promotion of cooperative development among supply chain businesses (Jiang et al., 2023). Blockchain, big data, artificial intelligence, and the Internet of Things are examples of digital technologies that have been incorporated into supply chain finance. These technologies have reduced financing costs, increased information

transparency, enhanced work efficiency, and improved supply chain integration overall (F. Chen, 2022). Additionally, it has been noted that supply chain management risks can be effectively managed through the usage of blockchain technology (Saber et al., 2018).

The advent of Industry 4.0 technology has made it possible to optimise supply chain operations in real time, which has enhanced the chain's dynamic capabilities and financial performance (Eslami et al., 2021b). The performance of businesses is greatly impacted by supply chain 4.0, which incorporates technology like big data analytics, sophisticated manufacturing technologies, robotics, and additive manufacturing (Liu & Chiu, 2021). Furthermore, the idea of "digital twins," made possible by digital technologies, enables the development of digital copies of supply chain processes, improving supply chain activity visibility and monitoring (Sani et al., 2022).

Digital technologies improve supply chain robustness and resilience in addition to improving operational efficiency. By establishing digital technologies as preconditions for improving supply chain resilience, they contribute to the development of supply chain memory (Alvarenga et al., 2023e). Transparency and efficiency are promoted by the integrated planning and control of logistics systems using digital models and tools, which is the focus of the digital supply chain (Rahamneh et al., 2023b). Additionally, the application of digital technologies to supply chain management fosters collaboration and trust across supply chain nodes as well as digital transformation within the chain (Ni et al., 2022b).

Supply chains now face disruption risks as a result of globalisation, which presents a challenge for businesses to successfully manage and reduce in order to maintain supply chain continuity (Kleindorfer & Saad, 2005), additionally, it has made conducting business globally more complex, creating difficulties with risk management, productivity growth, and long-term viability of such enterprises (Nguyen et al., 2020).

Leveraging Digital Technologies for Supply Chain Optimization

In the modern environment, digital technologies play a critical role in improving supply chain processes. For supply chains to remain efficient and competitive, digital technologies like blockchain, big data, artificial intelligence, and the Internet of Things are becoming more and more important (Akbari & Hopkins, 2022). With the use of these technologies, supply chains may increase visibility, reduce response times, and strengthen decision-making procedures (Akalin et al., 2022).

Digital technology have been essential in guaranteeing supply chain reaction and readiness during the COVID-19 pandemic. Through increased visibility and security, technologies such as blockchain have made a substantial contribution to increasing supply chain resilience and sustainability (Mak & Shen, 2020). Furthermore, it has been determined that digital supply chain integration is crucial for operational management, highlighting the need of relational and structural integration in supply chain operations (Cui et al., 2022).

Digital technologies are being integrated into supply chains to assist processes of continuous improvement and to increase operational efficiency. By assisting with error detection, cause identification, and solution proposal, these technologies support lean manufacturing concepts and prevent operational delays (Rahamneh et al., 2023c). Additionally, digital supply chain finance, which combines a number of technologies, promotes integration within supply chains, lowers costs, and increases labour productivity. (Y. Li & Chen, 2022).

Supply chains that have undergone a digital transition have resulted in standardized procedures and goods, adding value and attracting online buyers (Pyun & Rha, 2021c). Furthermore, the idea of "digital twins," made possible by digital technologies, permits the creation of digital copies of supply chain processes, improving visibility and activity tracking (Bhandal et al., 2022). In today's dynamic market, the use of digital technology in supply chain management has the ability to completely transform operations, boost productivity, and increase competitiveness (Salsas et al., 2021).

Evolving Role of Technology in Tackling Supply Chain Challenges

For modern supply chain management, technology plays a critical role in solving supply chain problems. Blockchain, AI, and big data are examples of technologies that have drastically changed supply chain operations and addressed a number of issues. For instance, supply lines can be made transparent, traceable, and secure thanks to blockchain technology, which also provides answers to global supply chain management problems (Saber et al., 2018d). The COVID-19 pandemic has highlighted the importance of technology in implementing resilience strategies and ensuring supply chain sustainability (Chowdhury et al., 2021).

The management of sustainable products and other important supply chain management goals are made possible in large part by digital technologies like blockchain (Kshetri, 2018b). There are chances for supply chain cost reduction and efficiency improvement with smart supply chain management, which is typified by intelligent decision-making and automation capabilities (Wu et al., 2016). Additionally, the digital transformation of supply chains can enhance operational efficiency, mitigate risks, and improve resilience and sustainability (A. Park & Li, 2021b).

Digital technology integration in supply chains facilitates lean manufacturing and other continuous improvement processes by providing real-time problem detection, cause identification, and solution proposal (Rahamneh et al., 2023d). Additionally, by strengthening supply chain memory and disruption management, digital technologies support supply chain robustness and resilience (Alvarenga et al., 2023f). The use of blockchain technology in supply chain operations promotes decentralized operations and information sharing, fostering collaborative operations among supply chain nodes (Xiao et al., 2020).

2.2 Review of Key Digital Technologies

The techniques of supply chain management are being profoundly impacted by digital technologies. Supply chains are changing because of several important technologies that are tackling various problems. An overview of some of the most well-known digital supply chain technology is provided below.

- **Block Chain:** Blockchain technology has emerged as a transformative tool in supply chain management, (Saber et al. 2018d) explain how blockchain technology enhances security, traceability, and transparency to address problems with global supply chain management. The decentralized nature of blockchain technology

makes data unchangeable and accessible to authorized parties, hence augmenting trust and accountability in supply chain transactions. (Y. Wang et al., 2019) discuss how blockchain technology has the potential to disrupt traditional supply chain practices by providing a secure and transparent platform for transactions. Blockchain, despite significant constraints like as scalability and integration, offers practitioners in the supply chain valuable insights into enhancing operational efficiency and data management. (Katsikouli et al. 2020) emphasize the benefits of blockchain technology for managing the food supply chain, with a focus on traceability that is more precise and faster. Blockchain-based systems provide real-time tracking of food products and reduce the time and effort required for traceability in the event of recalls or quality issues. (Difrancesco et al. 2022) explore how blockchain technology improves sustainable supply chain processes, offering practical guidance for implementation. The research highlights the swift development of blockchain technology and its possible uses in supply chain management, stressing how it might improve sustainability practices. (Y. Li & Chen, 2022) Discuss the benefits and drawbacks of blockchain technology for supply chains, keeping in mind concerns regarding security, intelligent manufacturing, governance, and transparency. Blockchain fortifies supply chains by reducing counterfeiting, raising product safety, and improving general supply chain management practices.

- Internet of Things (IoT): Supply chain management is greatly impacted by Internet of Things (IoT) technology, which improves connectivity and communication between digital systems and physical things. Numerous research works have illustrated how IoT can be used in supply chain management. (Aliahmadi et al. 2022) Talk about how IoT may boost information transmission efficiency in the supply chain by using big data and agile-lean principles to improve logistics in the pharmaceutical industry. (Raza et al. 2023) highlights how IoT may automate supply chain activities with sensors, actuators, and addressing devices in carriers and vehicles, hence enhancing operational efficiency. It also suggests a framework for blockchain-based agricultural food supply networks. (De Vass et al., 2018) Examine how IoT affects supply chain performance and integration from the standpoint of organizational

capabilities, with a focus on how IoT technologies enable the smooth integration of supply chain and logistics operations.

(Du 2022) analyses the effects and difficulties posed by IoT on supply chain management, focusing on how IoT technologies allow supply chain requirements to be tracked, agile, visible, and knowledge exchanged digitally. These technologies also provide useful indicators for process analysis and optimization. (Huang et al. 2022) present a brand-new intelligent supply chain management model built on the "Internet of Things + Blockchain," illustrating how the integration of IoT and blockchain technology improves supply chain visibility and operational transparency.

- **Artificial Intelligence (AI):** This technology significantly impacts supply chain management by enhancing decision-making, optimizing processes, and improving overall efficiency. (Baryannis et al. 2018) Talk about how artificial intelligence (AI) has produced automated systems that use data and knowledge to improve supply chain decision-making, possibly leading to increased operational efficiency and streamlined procedures. (Modgil et al. 2021b) emphasize AI as a tool to enhance supply chain resilience by developing business continuity capabilities. AI technologies can analyze data, predict disruptions, and enable proactive responses to maintain robust and adaptable supply chain operations. (Belhadi et al., 2021) Base your understanding of AI's application in supply chains on the idea of organizational information processing. By utilizing AI's capabilities, businesses can improve their supply chains' performance, resilience, and ability to adjust to changing market conditions. (Olan et al., 2022) Describe how supply chain resilience and performance are improved by AI-driven innovation, which offers automation, enhanced analytics, and predictive capabilities to streamline supply chain operations. (Gupta et al., 2022) Examine how artificial intelligence (AI) can be used to comprehend and assess options in dynamic supply chain scenarios. AI can process multidimensional data to help with informed decision-making and the successful navigation of supply chain interruptions.
- **Digital Twins:** Using digital twin technology, supply chain management may monitor, assess, and optimize operations by building virtual twins of physical assets, systems, or processes. (Ivanov & Dolgui 2020) Talk about how, in the age of Industry 4.0, Digital Twins may be used to

manage disruption risks and improve resilience. By simulating and analysing supply chain scenarios, businesses may use digital twins to improve their risk management and decision-making processes. (Barricelli et al. 2019) provide a comprehensive survey on Digital Twins, highlighting their definitions, characteristics, applications, and design implications. Digital twins are artificially intelligent virtual counterparts that link the real and virtual worlds and provide information for supply chain operations optimization. (Tang et al. 2023) provide a collaborative capability optimization methodology for smart manufacturing systems that is aided by digital twins. Businesses can improve supply chain operations, adjust to changing market demands, and improve production planning by utilizing digital twins. (Tao et al. 2018) introduce a product design framework driven by Digital Twins, emphasizing the technology's ability to bridge the physical and virtual worlds. Digital Twins facilitate product design, development, and testing, enhancing collaboration and innovation in supply chain processes. (Klar et al. 2023) Examine how supply chain twinning and smart city experiences can be applied to the use of digital twins at ports. Digital twins allow for sustainable planning and control of port logistics systems by providing simulation-based action recommendations.

- Additive Manufacturing/3D Printing: (Rogers et al. 2016) give a summary of the 3D printing services market, emphasizing any prospective shifts that may occur as additive manufacturing technology advances. The study highlights how the development of 3D printing services would affect supply chain management and company procedures. (Belhouideg,2020b) shows how 3D printing technology has helped overcome the shortage of essential medical supplies during emergencies and explores the influence of 3D printed medical equipment on handling the COVID-19 epidemic. (Sasson & Johnson,2016b) delve into the variability, supercentres, and supply chain reconfigurations associated with 3D printing orders. The study focuses on the ways that additive manufacturing, or 3D printing, affects supply chain operations and spare part management by turning digital blueprints into tangible products. (Beltagui et al.,2020b) explore the role of 3D printing and open design in fostering socially sustainable supply chain innovation. The study highlights how 3D printing technology can help overcome resource constraints and support the diffusion of

sustainable practices in supply chains. (Delić et al.,2019) provide empirical data demonstrating additive manufacturing's incorporation in the automobile sector and its possible influence on supply chain performance and integration. Significant potential for supply chain optimization and industry transformation exists with additive manufacturing.

- **Machine learning:** Machine learning is widely applied in supply chain management to improve efficiency, decision-making, and overall performance. Here are some benefits of utilizing machine learning in various supply chain sub-functions. (Ali et al., 2022) Discussions discuss how machine learning techniques can improve supply chain partner collaboration by analyzing data, seeing trends, and streamlining procedures. Machine learning can boost the efficiency of workflows in food supply chains by offering forecasting and analytical capabilities, which enable better decision-making and resource allocation (Re et al., 2021). Blockchain technology and machine learning can improve supply chain management transparency, data flow, and information exchange (Zhang et al., 2023).

2.3 Impact Digital Technologies in Supply Chain Sub-functions

A number of auxiliary tasks are involved in supply chain management, all of which are necessary for the smooth transfer of goods and services from suppliers to final consumers. Manufacturing, inventory control, logistics, and procurement are some of these sub-functions.

The process of finding, paying for, and obtaining products and services from vendors is included in procurement. It is essential for guaranteeing that the appropriate resources are acquired at the appropriate time and cost to fulfil customer and production expectations (Mentzer et al. 2001). The transit, storing, and distribution of goods along the supply chain are the main topics of logistics. It entails tasks like order fulfilment, warehousing, and transportation to guarantee prompt delivery of goods to clients (Selviaridis & Norrman, 2014). The task of keeping an eye on the stock levels along the supply chain falls to inventory management. In order to minimize holding costs and prevent stockouts, it entails anticipating demand, keeping an eye on inventory levels, and optimizing stock levels (Ketchen & Hult, 2006). Manufacturing is the process of creating products

out of components or raw materials. To guarantee that goods are produced effectively and in accordance with quality standards, it involves procedures including production planning, scheduling, and quality control (Lugada et al., 2022).

Digital technologies are revolutionizing a number of supply chain sub-functions, including production, inventory management, logistics, and procurement. The performance and efficiency of these sectors have significantly risen as a result of the integration of digitalization. Research has indicated that digital technologies facilitate the integration of processes, digitalization, automation, and improvement of analytical capacities. These outcomes lead to improvements in procurement, production, inventory control, and retailing. (Fatorachian & Kazemi, 2020).

The influence of digitalization in the procurement context is substantial. Studies underscore the significance of data analytics competencies in digital procurement and their impact on the entire operation of the supply chain (Hallikas et al., 2021). Through the use of digital technologies, procurement departments are moving from traditional administrative chores to strategic and value-adding positions within the supply chain (Seyedghorban et al., 2020).

Digital technologies are improving supply chain visibility and control, optimizing logistics and inventory management processes. To maximize material performance, production efficiency, and overall supply chain capabilities, the idea of digital twins in the supply chain is being investigated (Damtew, 2023). Additionally, the construction of intelligent supply chains is seen as a driver for the digital transformation of manufacturing enterprises, highlighting the interconnectedness of digital technologies across different supply chain functions (Liang et al., 2023).

2.4 Strategic Considerations and Adoption Challenges

Having digital technologies in place is not enough; it is also crucial for these technologies to be successfully implemented within enterprises. To guarantee that technological investments result in improved decision-making abilities, robust supply chain systems, and real-world efficiencies, a comprehensive approach to digital transformation is essential. To provide real advantages and generate competitive advantage, the emphasis is on not just using digital technologies but also doing so in a way that integrates them into the supply chain. Neglecting to integrate digital technology may result in disturbances to supply chain activities, which could affect the movement of goods, inventory control, and overall

effectiveness (Hofmann et al., 2019). Inefficient supply chain processes due to the failure of digital technology implementation can lead to increased operational costs, affecting the overall financial performance of the business (Luthra & Mangla, 2018). If businesses are unable to use digital technology for supply chain optimization, they risk losing their competitive advantage and becoming less competitive in the market (Hofmann et al., 2019). The performance of the business may be impacted by the failure to adopt digital technologies, which may lead to lost chances for process optimization, more visibility, and improved decision-making (Wu et al., 2016) and there are other numerous other examples which indicate the major business loss. So, implementing it effectively in the system becomes most important.

Aligning technology initiatives with business objectives and ensuring infrastructure readiness are critical to the strategic planning of technology adoption in supply chain management. (Paul & Chowdhury,2020) highlights how digital technology can play a major role in helping manufacturing supply chains implement strategy and recovery plans. This highlights how important it is to match digital activities with strategic goals.

(Fatorachian & Kazemi,2020b) Emphasize the significance of Industry 4.0 technologies in tackling integration obstacles by transforming supply chain management via sophisticated connection and all-encompassing integration. But interoperability issues, complexity, and outside variables like market dynamics and regulations can make it difficult to integrate digital technologies into supply chain functions smoothly (Lezoche et al., 2020). In addition, entities implementing digital technologies must navigate crucial factors such as information sharing challenges, complex system integration, and the requirement for strategic alignment with supply chain management goals (Vanpoucke et al., 2017). Blockchain adoption in supply chains is still hampered by the complexity of information systems integration, which highlights the necessity of careful planning and execution techniques (Shi et al., 2022b). Furthermore, issues like inadequate infrastructure, cybersecurity risks, and the necessity of resolving geographic barriers to integration underscore the complex nature of obstacles to the use of digital technology in supply chain sub-functions (Nozari et al., 2022). The significance of strategic planning in resolving integration issues is further highlighted by the complexity of supply chain coordination techniques and the requirement to go beyond conventional models (Bejlegaard et al., 2021).

Challenges in adapting digital technology in supply chain sub-functions, such as skill gaps, are critical barriers that organizations need to address to effectively leverage digital transformation. (Antony et al. 2021) highlights the impact of a shortage of digital skills and talents on the readiness and implementation of Quality 4.0, underscoring the need to bridge skill gaps for successful digital transformation. (Chatwattana 2021) highlights how crucial it is to close the skills gap needed for technological advancement, especially in developing nations, in order to take advantage of digital advancements and solve infrastructure issues. (Khamseh et al., 2021) draw attention to the difficulty of closing the pay and skill gap that exists between highly competent digital workers and workers in traditional professions, particularly in emerging nations, emphasizing the importance of skill development. (Da Silva Reis et al., 2021) concentrate on the competencies of supply chain management professionals in Brazil, stressing the significance of filling in skill gaps to improve supply chain operations' effectiveness and competencies.

Also, (Zhu & Liyanage 2021) examines important problems and obstacles pertaining to the safety instrumented systems cybersecurity in offshore oil and gas production assets, emphasizing the necessity of addressing cybersecurity issues in settings of digitalization.

The lack of implementation of digital technologies in supply chain management can result in various challenges and implications. Reference (Quayson et al. 2020) identifies adoption barriers that can prevent the effective integration of digital technologies in supply chains, including technical issues, low benefit awareness, mistrust, and implementation costs.

Many researchers have highlighted the need of mapping digital technologies in supply chain subfunctions in their studies. Similar to how a poor adoption rate and unsuccessful implementation can result from supply chain companies' and logistics professionals' ignorance of and lack of knowledge of digital technologies like blockchain and IoT (Kozhanov & Woebbeking, 2021). The effective integration of digital technologies in supply chains may be hampered by issues with interoperability and compatibility with current systems, as well as a lack of alignment between digital strategies and supply chain features (Ho et al., 2023c) Although research has been done on the moderating function of industry 4.0 technologies in supply chain dynamic capabilities, more study is required to determine the precise variables influencing supply chain dynamic capabilities and the impact of industry 4.0 technologies (Eslami et al., 2021).

Attention is also being drawn to the use of multi-criteria decision-making techniques for supply chain mapping in order to increase "visilience" (visibility and resilience) (Mubarik et al., 2023). The relationships between supply chain digitalization, adaptability, and sustainable development are also highlighted, as is the effect of supply chain mapping on cutting-edge business models (Zhou & Wang, 2021; Temjanovski & Dimitrova, 2023b).

In light of changing global problems and disruptions, supply chain mapping research is showing an overall trend toward a greater emphasis on utilizing digital technology, data analytics, and sophisticated methodology to improve supply chain visibility, resilience, and sustainability.

2.5 Performance parameters

As this research work is about comparing the case study analysis, this chapter outlines the importance performance parameters on which further comparison can take place. In case study analysis, performance parameters play a vital role in assessing the effectiveness and efficiency of organisation, furthermore it helps in comparing the outcomes of the case study analysis. So, it strengthens the research conclusion by providing the valuable insights. In order to assess the performance of technological advancements in supply chain sub-functions, here are the key-parameters which will be considered as an important driver for efficient supply chain operations.

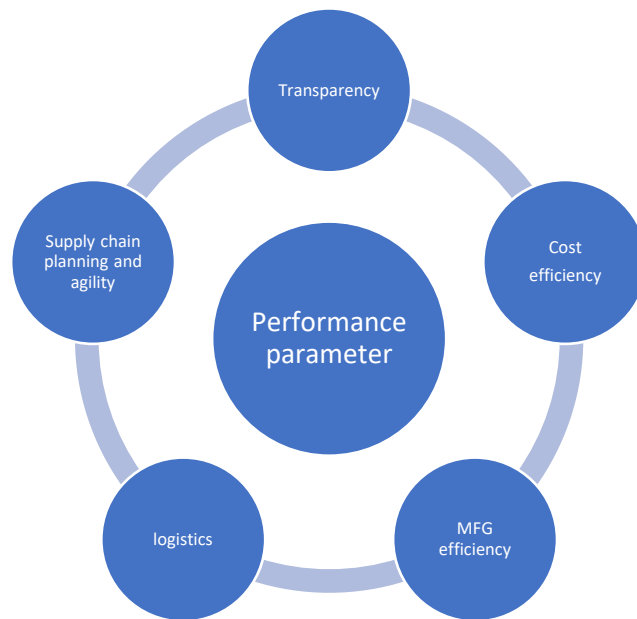


Figure 1 Key performance parameters for supply chain management (Researcher's finding)

- **Transparency across the supply chain stakeholders**

Supply chain transparency is an important factor in business operations as it allows better product traceability, communication and fosters ethical sourcing. Transparency in supply chain is about sharing the information about product, manufacturing process, material sourcing and environmental impact of business operations throughout the entire supply chain stakeholders (Schäfer, 2023). It enables the better visibility in supply chain operations and also allows the better communication across the value chain which further reduces the risk. Furthermore, transparent nature of supply chain has the profound positive impact on innovation through collaboration (Montecchi, 2021). Ultimately, transparency in supply chain enables the resilience, agility and also fosters the long-term relationship amongst the stakeholders and providing better economic impacts.

- **Cost efficiency**

In the dynamic landscape of the global commerce and fiercely competitive and changing consumer demands, need of effective supply chain management becomes the paramount. And to cost-efficiency in supply chain is one of the key parameters, which fosters the stronger supplier relationships through fair negotiations and bulk purchasing, reducing procurement expenses. Moreover, supply chain cost-efficiency also directly influences the customer satisfaction rate.

In the agile supply chain operations, business firm needs to have profitable in economic fluctuating situations. Cost efficiency in supply chain can be achieved through streamlining processes, optimising inventory and warehouse, minimising wastages and improving quality, this leads to improving higher product margin through reducing the operation cost. This parameter has been also added in the study, with a view of understanding how technology has ensured the supply chain cost-efficiency in business operations. In order to check that role of technology in reducing resource, improving manufacturing efficiency and reducing cost of wastage.

- **Production planning and efficiency**

Production planning and efficiency is one of the key parameters, which helps in understanding how business organisation is using their resources and how customers' demands are being met. Efficient supply chain operations ensure the smooth coordination between procurement, manufacturing, and distribution processes. It has the major influence on reducing lead-time and improving the efficiency (Towers, 2001). Efficient production planning involves the integration of customer demand, inventory management and resource optimisation. At the same time, effective production planning and accuracy in demand forecasting, helps in identifying the cost-saving opportunities such as batch-size of production and economies of scale (Zipfela, 2019). So, effective production planning helps in reducing the risk associated with organisational outcomes and also guides in having strategies to mitigate that.

- **Logistics effectiveness**

There are various advantages have been made in supply chain operations including logistics department, as it is amongst the critical activities. Effectiveness of the logistics is responsible for timely delivery of product and even directly related to the customer satisfaction rate (Kim S. T., 2020). But with the need of agile supply chain operations, logistics operations need to have the transparency in terms of real-time information and tracking ability of goods. Having efficient logistics ensures the responsive business functions, which helps in meeting the customer demands in least possible time (Islam, 2023). By prioritising the logistics operations and effectiveness, it results in better customer satisfaction rate, risk mitigation and streamlined operations.

- **Supply chain efficiency – Planning, agility, and forecasting**

Supply chain efficiency highly depends on planning, agility, and accurate forecasting. Effective supply chain planning involves the strategizing the movement of goods from supplier to the consumer in most effective way, without delay, this requires accurate coordination between inventory, customer forecasting and also about agile supply chain operation, ready to make changes according to the customer needs (Humdan, 2020). There are various technologies such as machine learning, AI, data analytics and many more software has advanced the supply chain planning operations. This is the main reason behind including it as a comparative parameter, to understand how technological advancements have made the supply chain planning more effective.

3 Case study analysis

Digital technologies are increasingly transforming the supply chain operations across the various industry, as suggested by the various researchers. So, to check the relevancy of digital technology in supply chain sub-function, case study analysis will show real-world case scenarios about how organisations are implementing the digital technologies across the various supply chain functions such as procurement, logistics, manufacturing, and inventory management. So, this chapter will show how digital technologies have performed in different companies for specific challenges, which will help in understanding the complexities and challenges associated with technological adoption with empirical evidence and examination of successful or unsuccessful results of the organisation. To achieve that, here four business firms have been selected which have been pioneer in their industry and have implemented digital technology in their supply chain operations. Selection of business firms have been made with a focus to checking impact of digital technology in different industries, to widen up the research perspective.

3.1 Zara

Zara is a Spanish Apparel company, famous for their trendy clothes and fast fashion globally. Company was started back in 1975 by Amancio Ortega and Rosalía Mera, with business aim of providing the low-priced fashion products, currently they are global leader and setting the fashion trend. Zara is a multinational fashion company, owned by Inditex group which is also a well-known and largest distribution company, currently they have business around 88 countries and having the stores around 2200 globally (MR, 2022). Zara handles the product designing and manufacturing process, whereas Inditex make sure the distribution and marketing. Company has the large product portfolio which includes apparels, perfumes, footwear category for all men, women and kids. Zara has the vision to implement the sustainable fashion and to reduce the pollution from their business innovation. With the central focus to attain all customer needs, company has reached the sales of €32.6 billion (35 billion USD) in the fiscal year of 2022, which is 23% higher than the previous year (Loeb, 2023). In order to improve the customer reach company has started focusing on the e-commerce channels, and resulted in sales of USD 6.162 billion in the year of 2022 (Statista, 2022) as shown in the figure below,

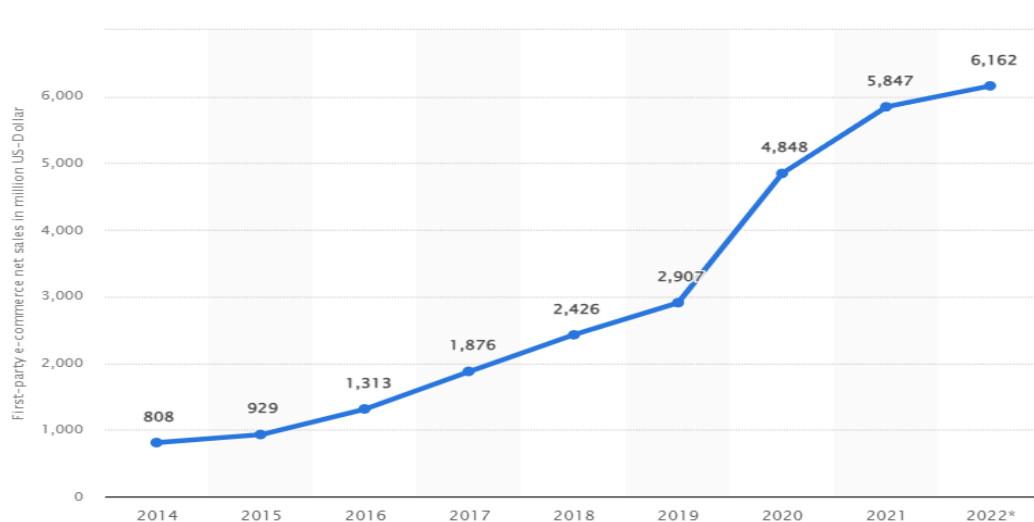


Figure 2 Zara online sales (Statista, 2022)

Major reason behind the success of Zara is technological advancements, company always stays at a forefront for making upgradation in technology and infrastructure. Company has integrated digital technology across the various supply chain operations includes manufacturing, inventory handling, planning and to the logistics. As Zara deals in a fast-fashion, this industry often criticised for overproduction challenges associated with it while customer-trends are getting changed in no-time. In order to overcome this company has made agile manufacturing, integrated with Artificial Intelligence, 3-D printing and data analytics. With the adaption of additive manufacturing like 3-D technology, as inclusion of 3D printers for assessing the new fast trends and changing consumer demands, has improved the garment development cycle, improves the quality, and has also removed chances of human error. Company has started integrating 3D printers since 2016, where they have developed first sweater made from 3D printer with the partnership of HP - Proto Labs (Canvanizer, 2022). Introduction of 3-D printers has helped Zara to shrink the garment development process cycle from month to the week with the mass customisation and manufacturing capability (Seemsay, 2021). With this advanced digital technology, company has half down the manufacturing time, which has helped company to reach market with least possible time.

Introduction of data analytics in production process, Zara collects the customer trend from various sources, includes customer feedback,

suggestions, social media trends and capturing information from search engines. With AI algorithms integrated with inventory and real-time data analytics they produce their products, which has helped in reducing lead time from 5 months to 25 days, and 30000 products annually (Roberts, 2023). In order to control the price of the product in fast-fashion industry, company has pricing strategy associated with “Just-in-time” production powered by AI and data analytics. Zara has integrated the Artificial intelligence algorithm with their production process, in order to have real-time information and design refinement has been achieved through computer-aided design systems, and changes are instantly transmitted to the relevant technologically advanced machines. This has helped in reducing the inventory and cost associated with maintenance of inventory. With the digital technologically powered manufacturing process, company has reduced the 10-15% of inventory handling cost (Ferdows, 2022), which has ultimately resulted in increase in profitability by 20% (Rishi, 2023). At the same time, company has achieved circular economy in their supply chain, where advanced digital technology has helped in collecting the used clothes and recycling them, from which they have collected 12,000 tonnes of used garments and has helped them in reducing the cost of demand for 700 million USD of virgin material, which ultimately results in better efficiency and productivity (Esbeih, 2021).

Digitalisation in Zara supply chain has started back in 2007, with just introduction of higher internet speed, but with the promising integration of digital technology in supply chain Zara has achieved the 240% of growth rate in just 10 years of the technological adoption (Uberoi, 2018). Company’s strategy to make agile supply chain is to have information collection from every pinpoint of the supply chain. Zara has integrated the RFID in every product they sale, with this they can gain the real-time information about the demand (AIX, 2023). This has helped them in having flexible supply chain as it allows the information to be flown 80% higher rate, which also results in getting trend analysis at faster rate (Uberoi, 2018). Technologically powered supply chain has helped Zara in reducing the lead time by 2-3 weeks, where they stand 3 months before advancements (Nagpal, 2023). At the same time, digitalisation backed flexible supply chain allows them for 50-60% of advance manufacturing only where other stands about 90% (Mhugos, 2023), this has resulted in only 10% of unsold products and their competitors have 20-25% (Ferdows, 2022).



Figure 3 fast-fashion growth rate (Uberoi, 2018)

Zara has also implemented the technology like IoT in their logistics operations, where they have focused more towards reducing the time to reach garment from factory to the customers. With the help of transparent supply chain and easy flow of information, Zara can replenish the in-store shelf in couple of weeks. This has helped in improving the distribution rate about 2-3 days in Europe and 24 hours in USA (Mickelson, 2018). Logistics has been the important part in Zara’s success and agile inventory management.

From the overall discussion, here are the all factors positively impacted by the technological development in Zara’s supply chain operations.

Table 1 Outcome of digitalisation in Zara (Researcher’s finding)

SCM planning	Transparent supply chain management <ul style="list-style-type: none"> • 80% faster information flow • Lead time reduced to 2 weeks from 3 months • Flexibility through 50-60% advanced production
Manufacturing	Flexible manufacturing through digital technology <ul style="list-style-type: none"> • Half the manufacturing time by 3D technology • Garment production cycle cuts from months to week
Inventory management	Real time information availability through RFID and blockchain

	<ul style="list-style-type: none"> • 10% less inventory through AI enabled forecasting • Only 10% unsold production result of optimised resource management
Logistics	<p>Continuous information flow through IoT</p> <ul style="list-style-type: none"> • Higher distribution rates from 2-3 days
Cost efficiency	<p>a) Profitability increased by 20% because of agile inventory handling</p> <p>b) Reduction in inventory and maintenance cost by 15%</p>

3.2 PepsiCo

PepsiCo is a global leader in food and beverage company, known for their brands like Lays, Pepsi, Doritos, Quakers and many more. Under the number of PepsiCo, company handles the 23 brands each of it generates \$1 billion. Company was started back in 1963 with the merger of Pepsi-Cola and Frito-lay, currently has the business in more than 200 countries and territories, and evolved into the largest food consumer company (PepsiCo, 2022). PepsiCo has the wide product range includes the soft-drinks, juices, snacks, and even ready-to-eat products, serving the different age-group, categories and life-style. Major reason behind the success of company in different territories includes the continuous innovation with central customer demand, marketing, and strategic partnerships (Britannica, 2022). Expanded business operations and wide product portfolio has resulted in great revenue generation about 86.39 billion U.S. dollars, which is almost 7 billion U.S. dollars higher than the previous year (Statista, 2022), as shown in the figure.

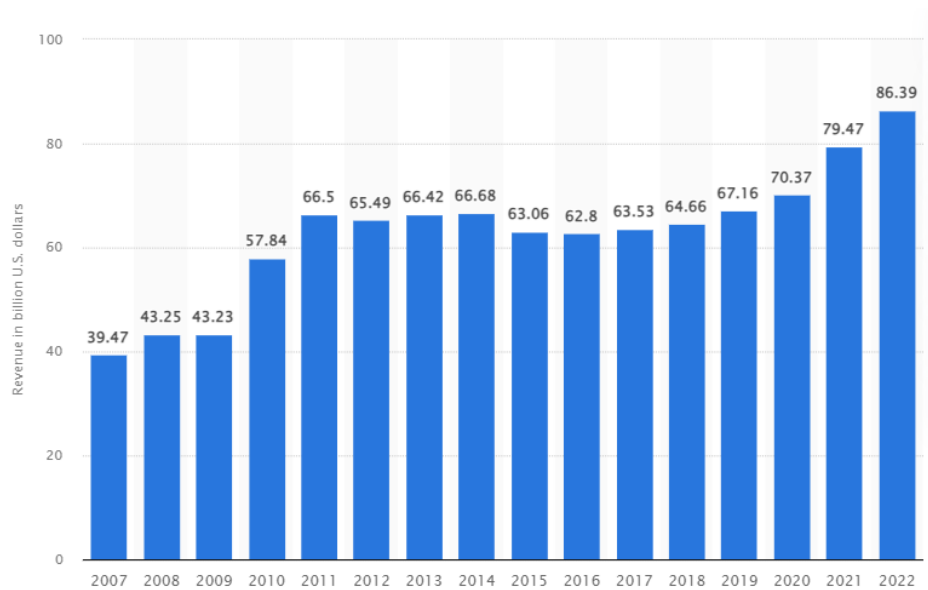


Figure 4 PepsiCo revenue (Statista, 2022)

As having the large product portfolio and expanded business operations, it becomes very complex for company to manage and poses a significant challenge in business efficiency. From the very beginning, company was intended for prioritising the technological changes and innovation for their broader capturing of consumer base. As during their business operations such as production, sales, marketing and distribution there is a big volume of data is generated and to generate the information from its PepsiCo has implemented big data analytics in their supply chain. from the various source of data like point of sales (POS), inventory data, logistics data, warehouse record and current market trend, helps in having the accurate forecasting, streamlined business processes and reduces the human error from the decision making (BS, 2021). Adoption of big data analytics and machine learning has helped managers in getting assisted for informed decision making as well as reducing margin error because of integrating wider source. Big data and Machine learning has helped PepsiCo in reducing the data analysis time by 70% and 90% reduction in decision making time compared to the conventional decision-making process (Tableau, 2022). This has improved the agility and flexibility in supply chain, which ultimately results in a responsive supply chain. Data collection from every point of the supply chain has improved the supply chain visibility about 35-40% across the all stakeholders (Elenjickel, 2023).

Usage of data analytics and machine learning algorithms have helped managers in getting better understanding of consumer preferences. This consumer preferences and prioritisation has helped in accurate customer segmentation and

developing the product according to the trending taste profile. Data analytics approach in the forecasting method has provided the company up to 90% forecasting accuracy for the six-month period (Contagious, 2018). Cloud based data analytics helped company to predict the consumer demand, as during the Quaker launch company analyses the 110 million household data about when to launch product and within 12 months of product launch, they have achieved 80% growth (Marr, 2019). Data analytics has helped company in getting 8% of annual growth with agile supply chain operations.

Digitalisation has also been spread to the manufacturing process of the PepsiCo, as they have integrated additive manufacturing for bottle production process. Integrating 3D technology in production process which has speed up the production process as well as reduces manufacturing cost. Conventionally there were a production time of 4-5 days which has reduced in 48 hours, while it has reduced the tooling cost by 96% and has provided the cost saving of \$1 million as an improved operational efficiency (MFG3D, 2022).

In Food and beverage industry, logistics and warehouse management play an important role, because of the perishable nature of the food. PepsiCo has enabled the IoT driven logistics which helps in providing the best quality of food to their customers by controlled temperature. At the same time, Sensors and IoT platforms provide the real-time information about the warehouse and inventory level, which has further improved the production planning and resource optimisation. AI-powered warehouse automation helps in identifying the exact level of inventory and work with 100% accuracy (Caulfield, 2023). This system is about deep learning-based AI label scanning device as shown in the figure below. Digitalisation in logistics and warehouse management has helped company in 25% reduction in delivery time, 33% reduction in chances of stockouts and 11% reduction in inventory handling cost (John, 2024). With the digitalisation PepsiCo is saving the transportation cost by 5% every year (Leung, 2022) as well as \$1 billion in productivity savings by leveraging the technology, connected business process and optimised routes (Dignan, 2023).

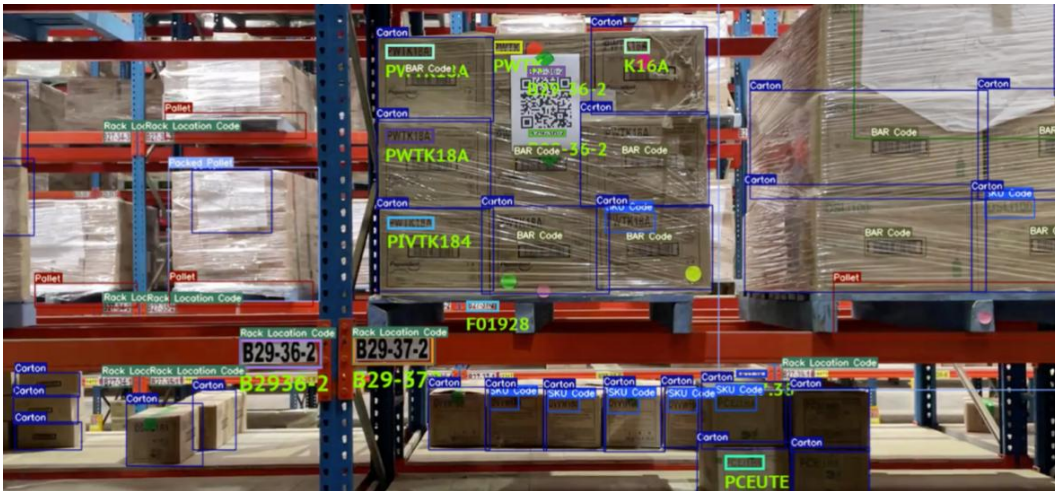


Figure 5 AI-driven warehouse management (Caulfield, 2023)

From the overall discussion here are all the advantages achieved by PepsiCo,

Table 2 Outcome of digitalisation in PepsiCo (Researcher's finding)

SCM planning	Visible supply chain management and planning <ul style="list-style-type: none"> • 35-40% improved visibility • 70% improvement in data analysis • 90%-time reduction in decision-making • 90% improved forecasting accuracy
Manufacturing	Flexible manufacturing through digital technology <ul style="list-style-type: none"> • Reduced the mfg. time by 48 hours from 5 days • 96% lower tooling cost
Inventory and warehouse management	Real time information availability through AI-driven algorithm <ul style="list-style-type: none"> • 11% less inventory through AI enabled forecasting • 100% accuracy in warehousing operations • 33% less chances of stockouts
Logistics	<ul style="list-style-type: none"> • 5% reduction in transportation cost • 25% lesser delivery time
Cost efficiency	c) 80% growth in 12 months

3.3 Ford

Ford Motor company founded in the year if 1903 by Henry Ford in Michigan, America, currently has the business across the 100 countries. Company's dedication towards the innovation and development, which has driven the automobile industry in a specific manner (Britannica, 2023). Strategic partnership and acquisition across, like China's Jiangling Motors the globe has made them a renowned and customer's choice of the company. Ford has the large supply chain including 65 manufacturing plants and 175,000 employees across the world (BQ, 2022). Ford handles all their supply chain operations including manufacturing, marketing and distribution world-wide. Ford's dedication towards attaining the customer expectation results in massive revenue generation every year, as they have registered 16% higher revenue generation which is about 158 billion USD, with a sale of 4.2-million-unit cars (Statista, 2022). Company has also worked towards sustainability as they have started introducing electric vehicles (EV) and hybrid vehicles in their product line-up. Addition to this company has the strong corporate-social-responsibility (CSR) programmes in their business operations like education, awareness programmes and health-care (Ford, 2023). This shows that company not only work towards the business, but has the strong belief in social sustainable development.

In the competitive nature of the automotive industry, Ford has put themselves always ahead in the market for making the changes to provide best travel experience to customers. Dedicated office for research and development in Michigan, hiring 100 expertise of different technology and invested 45 billion in it. Using 3D technology for prototyping in ford shows how business operations are centred towards advanced technology (CMF, 2022). Ford has integrated technologies like IoT and AI in their production plant to automating their manufacturing operations like welding and quality control. Using the IoT driven welding spot, this spot-welding robots saved the time of welding by 15% and at the same time has improved the welding accuracy compared to conventional method (FANUC , 2022). Using the AI in robotic arm and its application in assembling process, resulted in 15% less assembling time (Knight, 2021). and better material handling process. Same thing has been observed while metal forming process like stamping and pressing, which has helped in reducing the scrap waste by 40% and of 225 million USD and saves the 568,000 tons of scrap material (Energy, 2020). Integration of IoT in QC process has resulted in reduced manual operations and improved accuracy in supply chain. This has helped in improving the cost of poor

quality (COPQ) by 40% (Lauzier, 2021), manual operation reduction by 7%, tooling cost reduction by 6% (Knight, 2021).

In digitalisation of the whole process, Ford has integrated 5G technology across the whole infrastructure in order to overcome the issue of slow latency. This has helped in generating and improving the welding speed which helps in improving the responsiveness by 500,000 pieces of data per minute (GSMA, 2022). At the same time, 5G technology has helped in having the real-time data sharing across the different stakeholders which have improved the flexibility in supply chain.

In automobile industry, there are many parts are included in assembling of the vehicle, in such case inventory and warehouse management of the automotive has to be on-spot. Introduction of EVs in product portfolio has expanded the inventory of the automotive industry. Ford has used artificial intelligence and the Internet of Things (IoT) into their inventory handling processes to address this complexity. As a result, the company has been able to reduce inventory and associated costs by 75% (Mathas, 2021). Using the digital twin in the manufacturing process, helps in predictive analytics which has improved 3% savings and 15% improved operator efficiency (RH, 2023).

In order to improve the supply chain operations and visibility, ford has integrated blockchain technology for getting the better collaboration between suppliers and use digital ledgers for storing the transactions and streamline the supply chain operations (FA, 2023). With the mobility alliance MOBI, Ford has integrated the blockchain technology with partnership of IBM, which helps them in tracing the minerals from mines to the cathode plant in South-Korea (Mullan, 2023). This has improved the supply chain transparency across all stakeholders. At the same time, using the virtual reality (VR) in their training and testing stages, which has helped in having predictive analytics ultimately results in an efficient supply chain operation (Zhou, 2020).

Table 3 Outcome of digitalisation in Ford (Researcher's finding)

SCM planning	<ul style="list-style-type: none"> Improved supply chain visibility and secure information sharing through blockchain
Manufacturing	<ul style="list-style-type: none"> IoT driven welding helps in reducing welding time by 15% AI driven robotic arm reduces assembling time by 15%

	<ul style="list-style-type: none"> • COPQ improves by 40% • Manual operation reduction by 7%
Inventory and warehouse management	<ul style="list-style-type: none"> • 75% reduction in inventory and inventory maintenance
Cost-efficiency	<ul style="list-style-type: none"> • QC cost reduction – 6% • Cost saving from scrap reduction – 225 million USD • Predictive analytics results in – 3% cost saving

3.4 Samsung

Samsung electronics is an influential technology company in the world, which is well known-for their smartphones, Laptops and Computers. Samsung was founded in the year of 1938 by Lee Byung-chul as a trading company but further more they have diverted their business towards electronics and finance (Britannica, 2023). Company operates in 80 countries which has control over their manufacturing plants, marketing, distribution as well as make sure that they source the material in sustainable manner. Samsung stays forefront for the research and development, investing heavily in technological innovation and bringing the cutting-edge products to the market. Samsung has the wide electronic product portfolio, which includes television, tablets, smart-phones, tablets, Air-conditioners, refrigerators, Memory and many more. Company has shown the great growth of sales and revenue as 234.08 billion U.S. dollars (Statista, 2022). Smartphone and memory are the major source of revenue for the company, as shown in the figure below,

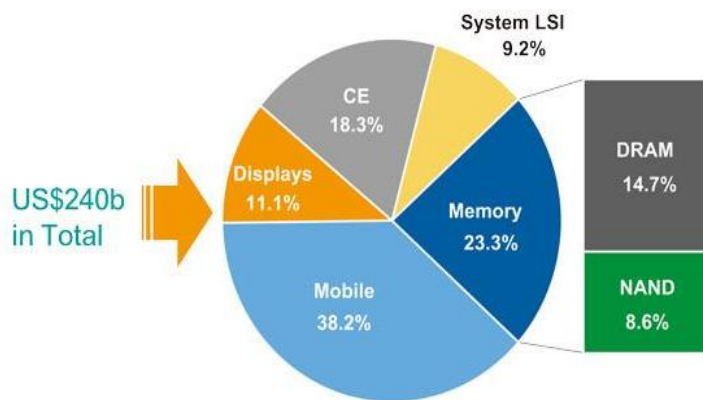


Figure 6 Category-wise revenue (Hwang, 2022)

Samsung is renowned company for their innovative products and active R&D programmes. In order to improve their supply chain operations company has implemented many technologies which includes 3D printing, blockchain technology in logistics, data analytics, Artificial Intelligence and many more. Company's active innovation towards chip production through second-generation 3nm without human intervention process and the generative Artificial Intelligence (AI). Integration of AI in chip production process helps in reducing the complexity of design. At the same time, these technological advancements have helped in improving the production process by 30% at the same time power consumption has been reduced by 50% as generative Artificial Intelligence helps in optimising the energy usage (SGN, 2022). To improve the work-efficiency across the channels, Samsung uses their algorithm model called "Samsung Gauss" such as composing emails and translating content. Using the 3D printing, helps in reducing the manufacturing of PCB boards at 20% lower cost compared to conventional manufacturing process because of lower waste generation and optimised resource usage (OPTOMEC, 2022). Company has integrated AI for quality checking in electronics, which has provided the 90% accuracy in QC whereas reduces the manual QC time by 60% (Forbes, 2022).

Samsung has the 2500 suppliers and distributors across the globe, which are responsible for global supply of Samsung electronics. Company handles the 488,000 tonnes of Air-cargo and a million twenty-foot equivalent unit (TEU) for shipping. This shows that company handles the big volume of logistics. In order to improve the supply chain transparency and logistics efficiency, company has introduced block-chain technology in their supply chain. Blockchain technology helps in automating the communication with the port authorities and internal communication, which makes faster communication free from any human confusion. According to the Song Kwang-woo, Chief of Samsung, Blockchain technology has helped them in recording the data and has allowed the governments to check the transaction data in secure manner (Kim S. , 2022). This technology has helped them in reducing the logistics cost by 20% with easy and seamless documentation and reducing the delays, at the same time allows the secure information sharing between the suppliers (Mouncer, 2023). Blockchain technology helps in automating the communication with the port authorities and internal communication, which makes faster communication free from any human confusion. According to the Song Kwang-woo, Chief of Samsung, Blockchain technology has helped them in recording the data and has allowed the

governments to check the transaction data in secure manner (Kim S. , 2022). At the same time, company has integrated the data from various sources to understand the consumer demand and having the flexible supply chain.

Company had found that difficulties in forecasting accuracy has resulted in excessive or shortage of inventory, in order to overcome that company has introduces the artificial intelligence and machine learning in their supply chain, which has further improved forecasting accuracy by 35-55%, which has improved the supply chain planning (MC, 2023). Integration of Artificial Intelligence in forecasting has allowed to generate the real-time insights and reduced the time by hours from the 3 days (AWS, 2023).

SCM planning	<ul style="list-style-type: none"> • 35-55% improved forecasting accuracy helps in optimised SCM planning
Manufacturing	<ul style="list-style-type: none"> • 30% improved performance analysis • 50% reduced power consumption • 90% accuracy in AI driven QC process • 70% manual time reduction
Logistics	<ul style="list-style-type: none"> • 20% reduced production cost
Cost efficiency	d) 80% growth in 12 months

4 Survey and interview findings.

From the early discussion in the research work, it is quite clear that research is going to check the influence or relevancy of technology in supply chain sub-functions. To achieve that research has included the case study analysis of the companies which have implemented advanced technology and to improve the research deepness, it has also added the expressions of the professionals working with an advanced technology while supply chain operations. Survey have been conducted with a view to understand which technologies have found the most applications in supply chain operations, influence of digital technology and to identify the challenges associated with. So, this part of the research outlines the survey conducted of the professionals, and demographics of the attendants have been discussed below in the table,

Participant code	Gender	Designation	Experience	Sector
Participant A	Male	Supply chain manager	0-3 yrs.	Technology
Participant B	Female	Logistics manager	0-3 yrs.	Fashion
Participant C	Male	Logistics manager	above 7 years	Manufacturing
Participant D	Male	Other	0-3 yrs.	Manufacturing
Participant E	Male	Other	3-7 yrs	Manufacturing
Participant F	Female	Supply chain manager	0-3 yrs.	Technology
Participant G	Male	Inventory manager	0-3 yrs.	Manufacturing
Participant H	Female	Other	0-3 yrs.	Fashion
Participant I	Female	Supply chain manager	3-7 yrs	Manufacturing
Participant J	Male	Procurement officer	0-3 yrs.	Manufacturing
Participant K	Male	Supply chain manager	above 7 years	Healthcare
Participant L	Male	Supply chain manager	0-3 yrs.	Retail
Participant M	Male	Procurement officer	3-7 yrs	Technology
Participant N	Female	Logistics manager	0-3 yrs.	Manufacturing

From the start of the research work and while designing the research question, research has been focused towards three main objectives, (a) identifying the key technologies in supply chain operations (b) understanding the impact of digital technologies in supply chain sub-functions and (c) to identify the challenges associated with it. With a view to have the comprehensive analysis and having the roadmap for implementation, survey have been conducted on three basis or themes. According to these research aims; three themes have been designed and data has been also collected according to it. following part of the research has outlined the key three themes on which data has been collected and analysed.

Theme 1	Key digital technology
Subthemes	<ul style="list-style-type: none"> • Technology for increased supply chain complexities • Technology in specific supply chain operations
Theme 2	Impact of Digital Technology
Subthemes	<ul style="list-style-type: none"> • Impact of digital technology in supply chain operations • Level of satisfaction from advancements in technology
Theme 3	Strategic consideration and challenges
Subthemes	<ul style="list-style-type: none"> • Current challenges associated with digital technology working • Key success-factors

4.1 Theme 1 - Key digital technology

Inclusion of key technology in supply chain operations shows the growing recognition of the digital technology in the supply chain operations. In the modern landscape, technology becomes the important factor in every business operation, but which technology has found the most applications in supply chain operations, needs to be answered. As there are various technologies which comes with different solutions and innovative options for single supply chain complexity. In such case, it becomes very important to discuss that technology which is most suitable in particular supply chain operations. So, with this aim research has been included with this key theme.

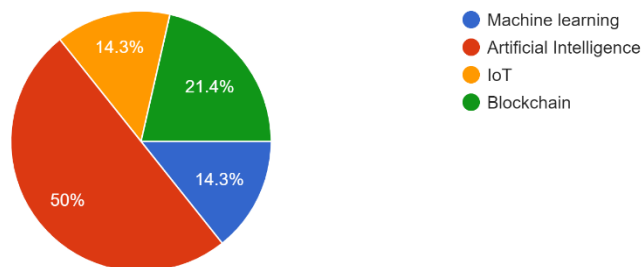
4.1.1 Technology for increased supply chain complexities

In the globalised business operations and ever-changing customer demands, supply chain complexities are getting increasing with diverse suppliers and market uncertainties. Transportation delays, inventory management complexities with e-commerce market and regulatory compliances have added the layers of intricacy. As discussed in the literature review, that supply chain operations have the conventional challenges associated with inventory handling, transparency, and logistical delays. There are various technologies which have found positive applications such as machine learning, Artificial Intelligence (AI) and Internet of Things (IoT). In order to identify the best technology, survey question has been added related to it and has been asked about technologies with best outcomes in

order to attain the supply chain complexities. Result of the survey has been shown below, and expression of respondents have been also discussed,

In your opinion, what are the key technologies which are relevant for current supply chain functions and increased complexities?

14 responses



As the figure suggests, most of the participants have found that Artificial Intelligence (AI) as a most useful technology in current supply chain complexities, as 7 out of 14 participants have agreed to have positive impact of AI on supply chain functions. At the same time 3 participants have found importance of blockchain in privacy and security related concerns. 28.6% of participants have responded that IoT and machine learning algorithms have played a major role in automating supply chain functions. Here are some expressions of the respondents about the key technology in supply chain operations

Participant C – “AI has revolutionaries the manufacturing industry with their ability of predictive analytics, advanced designing, and enhanced resource optimisation. Secondly it has made the supply chain more agile and responsive with added customer feedback and accurate forecasting”.

Participant J – “Impact of Artificial Intelligence on supply chain operations are transformative, with real time information availability and complete visibility in supply chain operations, it fosters the streamlining the operations and improved decision making”.

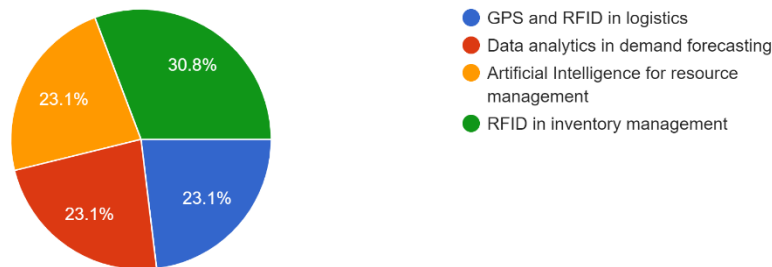
4.1.2 Technology in specific supply chain operations

Technology plays a vital role in improving the supply chain operations, with enhanced efficiency, transparency, and agility. Functions like inventory management, logistics, manufacturing and even sourcing have been highly influenced by the various innovative and latest technology advancements. Every organisation uses the same technology for different purposes, so to understand best technology for different supply chain operations, survey question has been

added to outline the experience of participant while carrying out different supply chain operations. Here is the result associated with survey and responses have been recorded and added further,

Are there specific digital technologies have been identified in your usage that have significantly changed the supply chain efficiency in your operations?

13 responses



As shown in the figure above mixed review of participants have been achieved must be because of their working background. As 4 respondents have suggested that RFID has the most positive influence in the inventory management because of the barcode scanning, monitoring the stock levels and streamlining the replenishments. At the same time, 3 respondents have identified the positive impact of GPS in logistics because of real-time information about movement of goods, and 3 have found positive application of data analytics in demand forecasting.

Participant G – *“precise location about movement of goods, remote monitoring of shipment and real-time data availability, has transformed logistics industry and it becomes possible because of inclusion of GPS in logistics operations”*

Participant A – *“In the continuous changing consumer demands and fluctuating market factors, data analytics have been pivotal in accurate demand forecasting and production planning”*.

4.2 Theme 2 - Impact of Digital Technology

Surveying about the impact of digital technology in supply chain operation is important as it guides in outlining the comprehensive insights about the evolving logistics and supply chain operations. Firstly, it will provide the extent at which digital technology has been implemented, which also guides in understanding the level of maturity of digital technology. Furthermore, research has added the

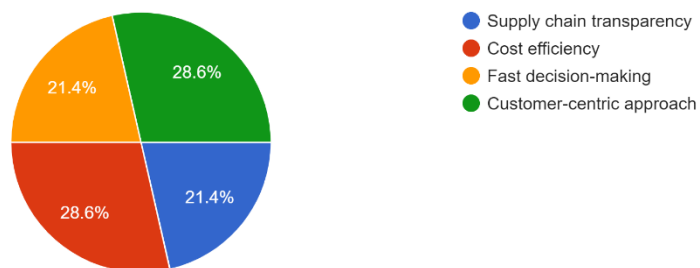
professionals of different industries, which have enabled the knowledge sharing and experience sharing from different industries and supply chain operations. So, to achieve the research objective and to understand the motives behind higher investments in digital technology, subthemes related to it has been discussed in this phrase of the research.

4.2.1 Impact of digital technology in supply chain operations

As discussed above that various technologies have been adopted in many supply chain operations. It has found to have the positive influence on supply chain cost efficiency and supply chain transparency. But to add the fresh expressions of the participants and to gain the experience of them while working with digital technology in supply chain operations, participants were asked about impact of digital technology in supply chain operations, and here is the result associated with it,

What are the key advancements have been achieved through the digital technology in supply chain sub-function in your organization?

14 responses



As the results shows that there is a diverse impact of digital technologies have been achieved. Every other participant has found the positive impact of digital technology but in different component of the supply chain. As 8 out of 14 participants have said that digital technologies have helped organisation in enhanced cost efficiency as well as assisted them in having customer-centric approach. At the same time 3 responded for having the supply chain transparency as well as have also suggested that digital technologies have found to have fast-decision making.

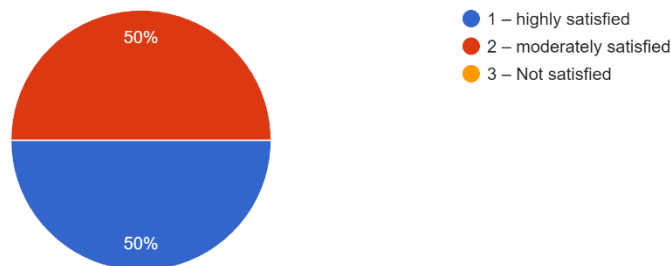
Participant E – *“Supply chain transparency is one of the key-supply chain operations influenced through the digital technology. Furthermore, organisations have made investments in technology just to improve the visibility, with a view to get a better control over the business operations”*

Participant B – *“Demand forecasting is quite difficult process in conventional business operations, but with the technological upgradation it gets highly updated with the higher accuracy”*

4.2.2 Level of satisfaction from advancements in technology

Because of the maturity level of the digital technology, there are mixed review of researcher have been found because of the challenges associated with it. So, to get the better understanding of it, survey question about the level of satisfaction of professionals while working with advanced technology. Here is the result of satisfaction level of technology advancements of employees working with it,

Rate the digital technology, about how it has made your work easy in terms of process efficiency and decision making
14 responses



As from the above figure, it is quite clear that all participants have gained some sort of positive impact of digital technology, as every manager associated with survey has been satisfied with digital technology, whether it is a highly satisfied or moderately satisfied. 50% of participants are highly satisfied with the technological advancements, whereas rest of responses are related to moderately satisfied, and being optimistic about technology upgradation.

Participant H – *“Implementation of digital technology in supply chain operations is highly satisfying in terms of reducing the manual work-load, minimising the iterative processes and eliminating the chances of human error”*

Participant L – *“Digital technology adoption in supply chain operations have been the satisfactory because of higher collaboration and enhanced transparency”*

4.3 Theme 3 - Strategic consideration and challenges

Having the various advantages of the technological advancements in the supply chain operations, implementing new technology is tricky part and needs to strategies it. In order to get the practical and real-world information about challenges associated with digital technology implementation, survey questions have been added in the survey and participants have happily shared their thoughts on it as discussed below.

4.3.1 Current challenges associated with digital technology working

In today's rapidly evolving landscape of the business, it has revolutionaries the supply chain operations with better efficiency and agility. However, alongside its' transformative potential, it comes with several challenges. Integration complexities between conventional infrastructure and latest technology, always hinders the seamless operations. So, to understand the challenges associated with implementation of digital technology, here are the expressions of participants,

Participant A - *Balancing the demand for faster, more transparent services with the capabilities of digital technologies.*

Participant B - *Difficulty integrating new digital technologies with existing systems and processes.*

Participant C - *Fear about the security of sensitive information and potential breaches affecting customer trust and compliance with regulations.*

Participant D - *Challenges in achieving real-time visibility across the supply chain due to disparate systems and lack of interoperability.*

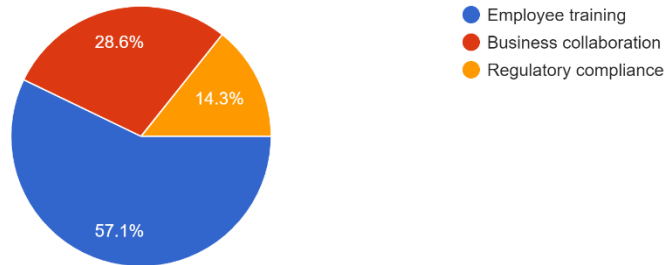
Participant E - *A shortage of skilled professionals capable of managing and optimizing digital technology implementations.*

4.3.2 Key success-factors

As integrating the new technology in existing business infrastructure needs proper change management, by prioritising the activities as per the objectives to be achieved. In order to have the seamless shifting from conventional to advanced technology, there will be need of identifying the key success factors for having the smooth change. To achieve that research question related to it has been added in the survey question and results are shown in the figure below,

What strategic consideration does your organization take into account when implementing the digital technologies in supply chain operations?

14 responses



As from the above figure it was quite clear that majority of participants have agreed that employee training is one of the key parameters while making the change, as 8 out of 14 participants have chosen it. At the same time, four out of 14 participants have suggested that business collaboration had been crucial while they were making change.

Participant N – *“employee training is a crucial element while making supply chain enhancements with technology, as it ensures the proficiency and confidence in employee about utilising new tools and technology”*

Participant D – *“Business collaboration is vital in technology advancements, as it fosters the collective innovation, experience sharing and maximises the benefits”*

5 Findings analysis

This section of the research delves into the findings and analysis derived from the comprehensive investigation carried out from the case study analysis and survey results. So, this chapter analyses how case study and survey results meets the research objectives and attains the research question stated above. This chapter is nexus between data collection and interpretation, which leads to the better conclusion of the research work. In order to check the digital technology relevancy in the supply chain operations, this study has included the case study analysis of the organisations which have successfully implemented digital technologies and expressions of the professionals working with an advanced technology in different parts of supply chain. So, this chapter analyses how digital technologies has attained the conventional challenges associated with supply chain and also outlines the technology which has the most impact on SC activities.

5.1 Empirical findings for key-performance parameters

This research work is about checking the impact of digital technology on the supply chain efficiency and productivity. So, to check that performance parameters have been identified in the literature review, results of this performance parameters help in checking the influence of digital technology.

Table 4 Key performance parameters analysis

	<u>Transparenc y</u>	<u>Cost- efficienc y</u>	<u>Manufacturin g efficiency</u>	<u>Logistic s efficienc y</u>	<u>Supply chain efficienc y</u>
<u>Zara</u>	✓	✓	✓	✓	✓
<u>PepsiCo</u>	✓	✓	✓	✓	✓
<u>Ford</u>	✓	✓	✓		✓
<u>Samsun g</u>		✓	✓	✓	

From the all case study analysis, it was found that digital technology has played a vital role in ensuring the transparency and visibility in the supply chain and stakeholders. All the companies have attained the positive results in supply chain

transparency, as digital technology has allowed the real time information sharing. Companies like PepsiCo has achieved the 34% increased visibility, whereas Zara has registered the faster information flow with increase in the pace of 80%, this has helped in generating reducing lead time.

All the companies have achieved the positive outcomes in terms of cost efficiency. Profound impact on predictive analytics and reduced manual intervention has helped companies in improving the supply chain performance. Results of ford suggests that they have achieved 6% lesser QC cost by IoT implementation at the same time saved 225 million USD by integrating AI in metal forming process. Zara has improved the 20% profitability by agile inventory management, shows the positive impact on cost efficiency.

Manufacturing efficiency is also one of the most influenced supply chain activities through the digital technology. Companies like Ford and Zara has implemented various digital technology like AI, IoT and machine learning in different manufacturing processes, which includes welding process, assembling process even helps in identifying mistakes in product designing process. They have achieved the reduction in 90% reduction in QC inspection, and Samsung has improved their manufacturing performance by 20%.

Logistics operations are greatly influenced by the technological advancements, which includes transparency in logistics and real-time information sharing. Temperature controlled logistics with IoT in PepsiCo and usage of blockchain in Ford for sharing the transactions securely is the ultimate examples showing the positive impact.

5.2 Relevancy of digital technology in attaining the conventional supply chain complexities

As this research work has the prime objective to check how digital technology can attain the complexities and challenges associated with the supply chain operations. From the literature review, it was found that conventional supply chain operations are highly impacted by the supply chain transparency, demand forecasting, resource optimisation and logistics related issues like information flow and its availability. So, this part of the research answers about how technology can attain the conventional supply chain complexities.

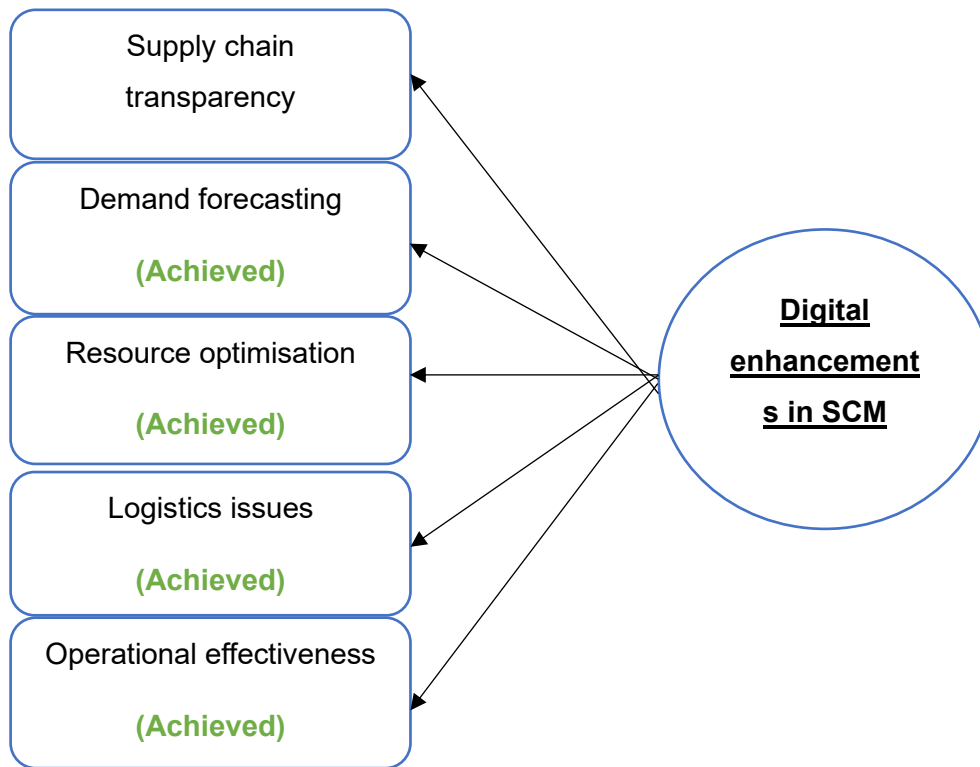


Table 5 Impact of digital technology on supply chain complexities (Researcher's finding)

As the shown in the figure and discussed in the case study analysis and survey, it was quite clear that conventional issues like supply chain transparency and demand forecasting are heavily attained through the technological advancements like data analytics and AI. These technologies have shown the better results in terms of forecasting accuracy like up to 90%. At the same time, technology like IoT and RFID can attain the issues related to logistics about information flow as well as revolutionaries the inventory management with the real-time information flow. Enhanced inventory management and warehouse optimisation have shown the positive impact towards resource optimisation.

So, from all discussion it can be said that all the complexities associated with the conventional supply chain can easily be attained with digital technology, as it backed by satisfaction rate of employees working with digital technology (50% employees satisfied with advanced technology). Technological advancements have not only registered for attaining the complexities but also has provided the pro-found impact on efficiency.

5.3 Digital technology and its' application

From the above discussion it is quite clear that digital technology has the positive impact on every supply chain operation and has improved the overall productivity of the business firm. But from the case study analysis and survey, it was found that every supply chain operation has the specific technology which has been adopted by every company and also mixed review have been achieved in survey results because of the diverse working background of participants, which drives the interesting insights of the research work.

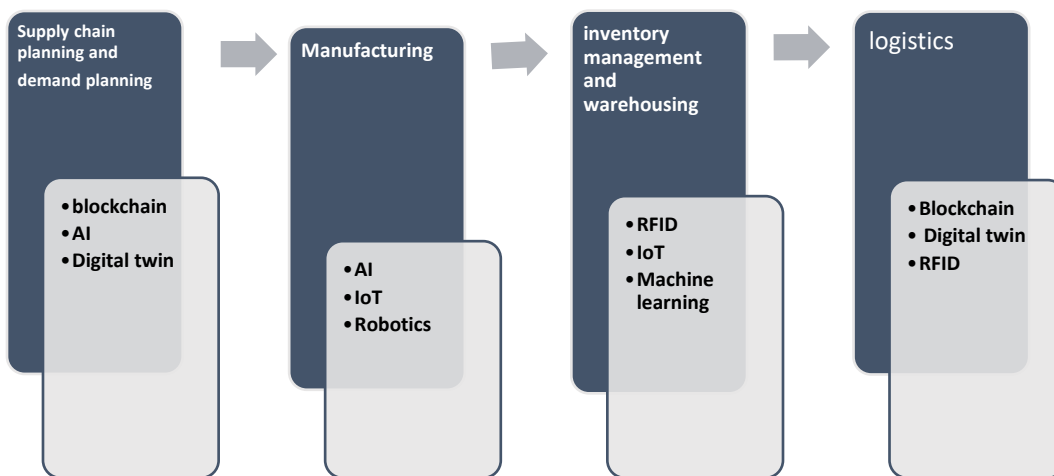


Figure 7 Digital technology and its' application (researcher's finding)

There are various technologies have shown the great outcome on supply chain operations which includes manufacturing, supply chain planning, warehousing and even logistics. But every operation has been found with specific technology. Artificial Intelligence and Machine learning algorithms have been adopted for the supply chain planning and demand planning. Technology like digital twin has also been adopted for supply chain planning and identifying the key issues in the supply chain strategies or implementation strategy making.

Case study analysis has shown that technologies like IoT and AI has been highly implemented in the robotics, which has helped in reducing the manual error integrated in it, whereas improved the productivity of the manufacturing plant. At the same time, results of the survey shows that implementation of AI in manufacturing can provide the optimised resource and data analytics for accurate demand forecasting.

Furthermore, technology like RFID and IoT sensors have revolutionaries the inventory management and logistics, as most of the companies have implemented it for getting real time-information. Survey and interview has outlines that RFID and IoT has gained the most interest in logistics industry and activities related to real-time information sharing.

5.4 Answers to research question

This part of the research strings back to the research question, which is about answering the research questions stated in the introduction chapter. This chapter helps in outlining how research has been conducted and provides the comprehensive view about research work and its' outcome.

i. What are the key digital technologies relevant for the supply chain functions?

Various digital technologies have been found to have impact on supply chain function, but blockchain has been found for secure transaction between stakeholders, Internet-of-Things (IoT) for real-time tracking of information between all supply chain elements, Artificial Intelligence (AI) for predictive analytics and forecasting of consumer trend, cloud computing has been found most application in higher data storage and online information sharing. These technologies have helped business firms to streamline supply chain operations, increased transparency and getting assistance in improved decision-making in supply chain management.

ii. How does digital technology impact the supply chain subfunction and efficiency?

Case study analysis and results of survey shows that organisations have achieved the multifaceted advantages in supply chain operations, related to reduction in human error as well as improved demand forecasting. Inventory management in manufacturing industry, real-time tracking of goods in logistics industry and demand forecasting through data analytics, are critical outcomes achieved through the digital technology advancements. Supply chain subfunctions have found to have positive efficiency through improving manufacturing efficiency, cost-savings by reducing errors and improved stakeholder collaboration by supply chain transparency.

iii. What are strategic consideration and challenges associated with implementation of digital technology?

From the case study analysis, it was found that strategic consideration to be made is to align the applications of technology with the organisational vision, business infrastructure and risks associated with it. At the same time, there has been challenges identified like upfront investment cost associated with it, skill, and knowledge gap as well as valuation of technology as it gets updated time to time. But survey results and data analysis of case study also suggests that, challenges can be attained through the strategic movement such as business collaboration and training programmes.

5.5 Overall analysis

So, the whole research was conducted in two parts, first one of about literature review, where various reviews of researchers have been discussed about impact of digital technology on supply chain operations and second part is about checking the relevancy of technology through the case study analysis and survey. Results of the both data collection method has been shown in the figure below,

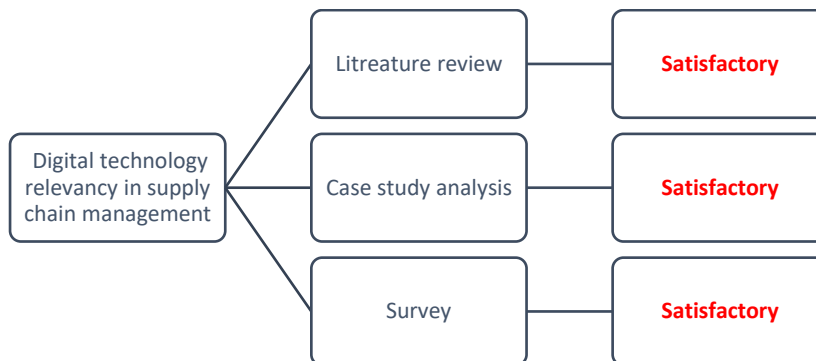


Figure 8 Overall research analysis (Researcher's finding)

From both sources of data collection, results were found satisfactory and in the direction which shows the positive impact of digital technology on supply chain complexities and has shown that it can improve the overall efficiency of the supply chain operations. As literature review and researchers have shown the influential impact of digital technologies, which is backed by the results of case study analysis and survey.

6 Key-drivers and challenges associated with digital technological advancements.

Having the various advantages of the digital technology, there are various challenges associated with advancements of technology and digitalisation, related to infrastructure and culture. This part of the research outlines the challenges associated with digitalisation in supply chain and its' implementation.

Challenges

a) Job displacements and cultural fit

This is one the prime challenge, associated with the digital technology advancements. There is a misconception that technology advancements will take away the job employees have (Rosenbaum, 2023). This becomes the challenge for managers and owner to have culture which adopt the new technology or change smoothly. Resistance to change becomes the highest challenge in the technological advancements. Results of the survey has also outlined that many participants have felt that adopting new culture in working area is quite difficult.

b) Skill and knowledge availability

As advancement is completely new set of technology and to communicate with it, there will be need of having skill or knowledge. Company like Ford also found the difficulty during the digital transformation in the year of 2014, because of skill set and lack of integration between conventional and new technology (Morgan, 2019). Conventionally working employees simply cannot work with the latest technology. So, not having proper skill or knowledge can bring the numerous challenges to the technological development.

c) Upfront financial cost

It is one of the most discussed challenges that company needs to invest higher amount of cost while making technological change. Also, case study analysis has shown that companies have invested millions and billions of dollars to making infrastructural changes and availing the right skill in the business environment. Samsung has invested 4 million USD for Blockchain technology integration in logistics (Kour, 2021), ford invested about 45 million USD for additive manufacturing (Ford , 2023). For small company it is not possible, as there will be need of compromising and ensuring the various priorities.

d) Cybersecurity and privacy concerns

This is one of the challenges associated with the digital technology in their various applications. Because technology is at pre-mature stage, these concerns are going to take place about privacy and cyber-security. And while applying these technologies in business infrastructure it will going to ask big challenge as it is directly related to brand image and customer privacy.

Key-drivers

In order to overcome the challenges associated with implementation of the digital technologies, there will be need of outlining the key-drivers. Key-drivers are the main parameters which have the direct impact on seamless integration in conventional infrastructure.

a) Business collaboration

Business collaboration is one of the important key-driver in digital technology advancement, where companies outsource their business activities or technological advancements related processes to the other companies. This helps in getting more focused on core business goals rather than just act towards technological enhancements. Business collaboration encourages the innovation and allows using resource efficiently. Samsung has integrated with KZen networks and LGUplus for their blockchain enabled supply chain operations (Kour, 2021).

b) Continuous innovation

As stated above that digital technologies have been found to have the issue related privacy and security. In such case, there will be need of making continuous upgradation of technology, which will help in getting maximum benefits of the technology. This pattern has been also observed in case studied companies that they have actively focused towards innovation and research. Survey results also suggests that continuous innovation in the digital technology plays a vital role.

c) Infrastructural development

Making infrastructural development is utmost important in the digital technology. As there is a need of higher data storage capacity, higher speed of information sharing and sensors to collect data at higher speed. In order to gain the maximum benefits from the technological change, there will be need of making infrastructural development, which facilitate the organisational goal.

d) Training programmes

This is one of the most important critical success factors identified in the case study analysis that, companies have actively focused towards training their employees. This is one of the root causes behind getting successful outcomes. Training programmes helps employees in understanding the technology as well as guides in how to act in emergency situation.

7 Recommendation

From the overall discussions and findings of case study analysis, here are some of the common factors observed throughout the study. Stretching the success factors stated above, this section of the research outlines the recommendation for the organisations, which helps in having smooth transition from conventional to advanced technological infrastructure working culture,

Recommendation 1	Training programmes for employees about advanced digital technology.
Rationale	Training programmes about the latest technologies plays a crucial role in bridging the gap between workforce skill-set and efficient operations. Having the proper training sessions makes the workforce fierce with the advanced tools, which helps in smooth communication between employees and machines, this furthermore helps in tackling any critical situation with innovative ideas. At the same time, it helps in having confidence to the workforce about usage of technology by providing the utmost knowledge.
Ownership	HR department and organisations
Cost and resources	\$600-800 USD Resources – Physical infrastructure - training room Digital infrastructure - Training channels / online sources Internet connectivity Educational material – software and books
Time	An online workshop with a longer time-period can be conducted in single day or it can be spread over the week with shorter daily sessions.
Challenge and barrier	Training programmes are often considered as a additional cost and management finds it financial burden for having it, and also the time constraint related to training of working employee is also critical challenge.

Recommendation 2	Infrastructural readiness for digitally advanced technology
Rationale	As digital technology is quite new technology and it needs the completely new infrastructure in terms of data storage capability as well as infrastructure related to data analysis. It provides the seamless integration of new technology as well as provides the maximum benefits of latest technologies through organisational long-term goal achievements.
Ownership	Tech department
Cost and resources	Cost - On an average of \$2000-6000 USD Resources – data-base management system Cloud storage Data analytics and algorithms IT team – consulting and professional services
Time	Time-frame for initiating changes and executing latest technologies can ranges from 6 months to 8 months depending on the nature of implementation, whether it involves a joint venture or outsourcing.
Challenge and barrier	Making infrastructural changes needs the big volume of financial investment, which can hinder the benefits of digital technology. Because there is a need of investments related to hardware cost, software cost, data migration and storage cost, and many more. This can be the barrier for many companies to allocate this big amount.

Recommendation 3	Business collaboration or outsourcing with technologically advanced companies
Rationale	As stated above that technological advancements have asked for many infrastructural changes, training of employees to work with it as well as to design it as per the

	<p>company specification. In such case, it becomes hectic for organisation's employee to follow their routine work and to implement new technology. In such case, having the business collaboration with another technical advanced business firm, helps in resource optimisation, knowledge sharing and provides cost-effectiveness and also better control over project outcome. Making business collaboration, helps organisation to focus on their core activity rather than providing much time in technological advancements.</p>
Ownership	Organisational management
Cost and resources	<p>Cost - On an average of \$40000-60000 USD (depends on project)</p> <p>Resources – policy making Business partnership framing Cross-functional teams Communication platform Contracts and agreements</p>
Time	<p>Business collaboration is quite complex process, as there is a need of identifying and designing the policies before making any collaboration, this can take time up to six months or it can be completed in one week if everything goes in a smooth manner.</p>
Challenge and barrier	<p>There is a key challenge associated with collaboration and outsourcing that it may find the losing of control over the business activities, because of least involvement.</p>

8 Conclusion

From the end of the discussion, it can be concluded that technological advancements have the positive impact on the supply chain sub-functions. It can be stated that the influence of digital technology in supply chain operations are multifaceted, as it provides the benefits of predictive analytics in the manufacturing sector as well as enables the real-time information sharing in the logistics industry through GPS.

Research has been conducted with two basic objectives about identifying the key technology in an uncertain market and to understand the impact of digital technology in supply chain subfunction. As there are various literatures about stating the positive impact of digital technology in supply chain operations, but these literatures have failed in providing practical results and implementation challenges. So, with a view to attain this literature gap, research has been conducted to check the relevancy of the key digital technology in supply chain operations through the ability of it to attain the complexities associated with conventional operations. Literature has outlined the complexities such as transparency issues, demand forecasting issues, complexities associated with resource optimisation and issues linked with logistics efficiencies.

Results of the case study show that multinational companies have got phenomenal results through the implementation of digital technologies, such as Ford has achieved the better inventory and quality control through IoT as a reduction in COPQ by 40%, at the same time PepsiCo has achieved the 90% reduction in time for decision making and also attained the 90% accurate forecasting, through the data analytics. Furthermore, research has also stated the satisfaction level of professionals working with digital technologies, stating that every professional has got the positive influence of digital technology in it, and because every employee has the different background of working there is a mixed review has been achieved in the impact of digital technology on supply chain sub-functions, as 7 respondents agreed for the positive impact of RFID in inventory whereas some found data analytics in demand forecasting.

From the whole discussion of case study analysis and survey, it was observed that various technologies have found the positive impact but every supply chain function demands the specific technology. As results of case study and survey show that inventory management has been highly influenced by the technology like RFID and GPS, AI and Digital twin has found most applications in demand

planning as shown in Zara, furthermore case study of Ford suggests that Robotics and IoT has revolutionaries the manufacturing sector.

From the overall discussion, research can be concluded that digital technologies have the positive impact in the supply chain operations. In the current market uncertainties and volatility of market fluctuations, making digital technological advancements becomes the necessity as it provides the competitiveness through better efficiency and cost-saving. Although there are challenges associated with implementation of advanced technologies, but recommended strategies can help organisations to have smooth transition.

8.1 Future work recommendation

This research has been solely focused towards stating the relevancy of digital technology in supply chain subfunctions. But this research can be more diverse with adding the factors related to advancements related to data security and privacy issues, regulatory compliances and role of technology in sustainable development. So, it is recommended to stretch this research work to the above discussed topics to get a comprehensive research work.

9 Survey

Section 1 – key digital technology

1.1. In your opinion, what are the key technologies which are relevant for current supply chain functions and increased complexities?

- a) Machine learning
- b) Artificial Intelligence
- c) IoT
- d) Blockchain

1.2. Are there specific digital technologies have been identified in your usage that have significantly changed the supply chain efficiency in your operations?

- a) GPS and RFID in logistics
- b) Data analytics in demand forecasting
- c) Artificial Intelligence for resource management
- d) RFID in inventory management

Section 2: Impact of Digital Technology

2.1 What are the key advancements have been achieved through the digital technology in supply chain sub-function in your organisation?

- a) Supply chain transparency
- b) Cost efficiency
- c) Fast decision-making
- d) Customer-centric approach

2.2. Rate the digital technology, about how it has made your work easy in terms of process efficiency and decision making

- a) 1 – highly satisfied
- b) 2 – moderately satisfied
- c) 3 – Not satisfied

Section 3: Strategic Considerations and Challenges

3.1. What strategic consideration does your organisation take into account when implementing the digital technologies in supply chain operations?

- a) Employee training
- b) Business collaboration
- c) Regulatory compliance

3.2. What challenges have you encountered or foresee while implementing or communicating with the digital technology?

10 References

AIX. (2023). Case Study: Zara's Comprehensive Approach to AI and Supply Chain Management. Retrieved from <https://aiexpert.network/case-study-zaras-comprehensive-approach-to-ai-and-supply-chain-management/#:~:text=Key%20Takeaways,stage%20of%20the%20business%20process>.

Ada, N., Kazançoğlu, Y., Sezer, M. D., Ede-Senturk, C., Ozer, I., & Ram, M. (2021). Analyzing barriers of circular food supply chains and proposing industry 4.0 solutions. *Sustainability*, 13(12), 6812. <https://doi.org/10.3390/su13126812>

Akalin, G. I., Corredor, F., Karpak, B., & Illia, A. (2022). Impacts and implications of Digital Technology use in Supply Chain preparedness and response during the COVID-19 Pandemic. *Journal of Information Systems and Technology Management*, 19. <https://doi.org/10.4301/s1807-1775202219019>

Akbari, M., & Hopkins, J. L. (2022). Digital technologies as enablers of supply chain sustainability in an emerging economy. *Operations Management Research*, 15(3–4), 689–710. <https://doi.org/10.1007/s12063-021-00226-8>

Ali, N., Ghazal, T. M., Ahmed, A., Abbas, S., Khan, M. A., Alzoubi, H. M., Farooq, U., Ahmad, M., & Khan, M. A. (2022). Fusion-Based supply chain collaboration using machine learning techniques. *Intelligent Automation and Soft Computing*, 31(3), 1671–1687. <https://doi.org/10.32604/iasc.2022.019892>

Aliahmadi, A., Nozari, H., & Ghahremani-Nahr, J. (2022). Big Data IoT-based Agile-Lean logistic in pharmaceutical industries. *International Journal of Innovation in Management Economics and Social Sciences*, 2(3), 70–81. <https://doi.org/10.52547/ijimes.2.3.70>

Alvarenga, M. Z., De Oliveira, M. P. V., & Oliveira, T. (2023e). The impact of using digital technologies on supply chain resilience and robustness: the role of memory under the covid-19 outbreak. *Supply Chain Management*, 28(5), 825–842. <https://doi.org/10.1108/scm-06-2022-0217>

Alzoubi, H. M., & Ramakrishna, Y. (2020). Investigating the mediating role of information sharing strategy on agile supply chain. *Uncertain Supply Chain Management*, 273–284. <https://doi.org/10.5267/j.uscm.2019.12.004>

Antony, J., Sony, M., McDermott, O., Jayaraman, R., & Flynn, D. (2021). An exploration of organizational readiness factors for Quality 4.0: an intercontinental

study and future research directions. *International Journal of Quality & Reliability Management*, 40(2), 582–606. <https://doi.org/10.1108/ijqrm-10-2021-0357>

AWS. (2023). Samsung Electronics Improves Demand Forecasting Using Amazon SageMaker Canvas. Retrieved from <https://aws.amazon.com/solutions/case-studies/samsung-electronics-amazon-sagemaker-case-study/>

Barricelli, B. R., Casiraghi, E., & Fogli, D. (2019). A survey on Digital Twin: Definitions, characteristics, applications, and design implications. *IEEE Access*, 7, 167653–167671. <https://doi.org/10.1109/access.2019.2953499>

Baryannis, G., Validi, S., Dani, S., & Antoniou, G. (2018). Supply chain risk management and artificial intelligence: state of the art and future research directions. *International Journal of Production Research*, 57(7), 2179–2202. <https://doi.org/10.1080/00207543.2018.1530476>

Basana, S. R., Ubud, S., Malelak, M. I., & Tarigan, Z. J. H. (2023b). The effect of key user capability on supply chain digital and flexibility in improving financial performance. *Uncertain Supply Chain Management*, 11(1), 267–276. <https://doi.org/10.5267/j.uscm.2022.9.016>

Bejlegaard, M., Sarivan, I., & Wæhrens, B. V. (2021). The influence of digital technologies on supply chain coordination strategies. *Journal of Global Operations and Strategic Sourcing*, 14(4), 636–658. <https://doi.org/10.1108/jgoss-11-2019-0063>

Belhadi, A., Mani, V., Kamble, S. S., Khan, S. a. R., & Verma, S. (2021). Artificial intelligence-driven innovation for enhancing supply chain resilience and performance under the effect of supply chain dynamism: an empirical investigation. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-03956-x>

Belhouideg, S. (2020b). Impact of 3D printed medical equipment on the management of the Covid19 pandemic. *The International Journal of Health Planning and Management*, 35(5), 1014–1022. <https://doi.org/10.1002/hpm.3009>

Beltagui, A., Kunz, N., & Gold, S. (2020b). The role of 3D printing and open design on adoption of socially sustainable supply chain innovation. *International Journal of Production Economics*, 221, 107462. <https://doi.org/10.1016/j.ijpe.2019.07.035>

Bhandal, R., Meriton, R. F., Kavanagh, R., & Brown, A. C. (2022). The application of digital twin technology in operations and supply chain management: a

bibliometric review. *Supply Chain Management*, 27(2), 182–206.
<https://doi.org/10.1108/scm-01-2021-0053>

Billah, M. M., Alam, S. S., Masukujjaman, M., Ali, M. H., Makhbul, Z. K. M., & Salleh, M. F. M. (2023). Effects of Internet of Things, supply chain collaboration and ethical sensitivity on sustainable performance: moderating effect of supply chain dynamism. *Journal of Enterprise Information Management*, 36(5), 1270–1295. <https://doi.org/10.1108/jeim-06-2022-0213>

BQ. (2022). Ford's Number of Manufacturing Plants by Location. Retrieved from <https://businessquant.com/ford-manufacturing-plants-by-location>

Britannica. (2022). PepsiCo, Inc. Retrieved from <https://www.britannica.com/topic/PepsiCo-Inc>

Britannica. (2023). Ford. Retrieved from <https://www.britannica.com/topic/Ford-Motor-Company>

Britannica. (2023). samsung. Retrieved from <https://www.britannica.com/topic/Samsung-Electronics>

BS. (2021). PepsiCo Looks to Analytics to Improve \$2 Billion E-Commerce Business. Retrieved from <https://brainstation.io/magazine/pepsico-looks-to-analytics-to-improve-2-billion-e-commerce-business>

Canvanizer. (2022). Zara Inclusion of 3D printers. Retrieved from <https://canvanizer.com/print-plan/rUWbL1ys6Sum4>

Caulfield, B. (2023). PepsiCo Leads in AI-Powered Automation With KoiVision Platform. Retrieved from <https://blogs.nvidia.com/blog/pepsi-koivision/>

Chansamut, A. (2023). Supply Chain Management information system for vaccines management in Thailand. *International Journal of Supply Chain Management*, 12(2), 42–46. <https://doi.org/10.59160/ijscm.v12i2.6130>

Chen, F. (2022). Application of Fintech in supply chain financial risk control. *Advances in Computer Science Research*. https://doi.org/10.2991/978-94-6463-108-1_90

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

CMF. (2022). Ford Motor Enters Digital Era With Its Advanced Manufacturing Center. Retrieved from <https://connectedmanufacturing.wbresearch.com/blog/ford-motor-company-advanced-manufacturing-center-strategy#:~:text=With%20its%20commitment%20to%20cutting,now%2C%20and%20into%20the%20future.>

Contagious. (2018). How PepsiCo is using predictive analytics to streamline product development. Retrieved from <https://www.contagious.com/news-and-views/how-pepsico-is-using-predictive-analytics-to-streamline-product-development>

Croom, S., Vidal, N., Spetic, W., Marshall, D., & McCarthy, L. (2018). Impact of social sustainability orientation and supply chain practices on operational performance. *International Journal of Operations & Production Management*, 38(12), 2344–2366. <https://doi.org/10.1108/ijopm-03-2017-0180>

Cui, L., Wu, H., Wu, L., Kumar, A., & Tan, K. H. (2022). Investigating the relationship between digital technologies, supply chain integration and firm resilience in the context of COVID-19. *Annals of Operations Research*, 327(2), 825–853. <https://doi.org/10.1007/s10479-022-04735-y>

Da Silva Reis, M. A., Minerbo, C., & De Souza Miguel, P. L. (2021). SCM professionals' competences in Brazil. *Brazilian Journal of Operations & Production Management*, 18(4), 1–17. <https://doi.org/10.14488/bjopm.2021.024>

Damtew, A. W. (2023). Roles of digital twins on material performances and utilization on upstream industry (The case of automotive industry). *Research Square (Research Square)*. <https://doi.org/10.21203/rs.3.rs-2659308/v1>

De Vass, T., Shee, H., & Miah, S. J. (2018). The effect of “Internet of Things” on supply chain integration and performance: An organisational capability perspective. *Australasian Journal of Information Systems*, 22. <https://doi.org/10.3127/ajis.v22i0.1734>

Delić, M., Eyers, D. R., & Mikulić, J. (2019). Additive manufacturing: empirical evidence for supply chain integration and performance from the automotive industry. *Supply Chain Management*, 24(5), 604–621. <https://doi.org/10.1108/scm-12-2017-0406>

Difrancesco, R. M., Meena, P. L., & Kumar, G. (2022). How blockchain technology improves sustainable supply chain processes: a practical guide. *Operations Management Research*, 16(2), 620–641. <https://doi.org/10.1007/s12063-022-00343-y>

Dignan, L. (2023). PepsiCo has its technology, process game down. Retrieved from <https://www.constellationr.com/blog-news/insights/pepsico-has-its-technology-process-game-down>

Duoming, H., & Chin, T. A. (2022). A Systematic review for supply chain integration and risks. *International Journal of Academic Research in Business & Social Sciences*, 12(1). <https://doi.org/10.6007/ijarbss/v12-i1/11856>

Du, J. (2022). The impact and challenges of the internet of things (IoT) on supply chain management. *Advances in Economics, Business and Management Research*. <https://doi.org/10.2991/aebmr.k.220603.202>

Elenjickel, M. (2023). Lessons in Supply Chain Digitization from PepsiCo and Conagra. Retrieved from <https://www.fourkites.com/webinars/lessons-in-supply-chain-digitization-from-pepsico-and-conagra/>

Energy. (2020). Ford to Cut Landfill Waste by 40% per Vehicle. Retrieved from <https://energydigital.com/smart-energy/ford-cut-landfill-waste-40-vehicle>

Esbeih, K. N. (2021). Transition to the Circular Economy in the Fashion Industry: The Case of the Inditex Family Business.

Eslami, M. H., Jafari, H., Achtenhagen, L., Carlbäck, J., & Wong, A. C. (2021). Financial performance and supply chain dynamic capabilities: the Moderating Role of Industry 4.0 technologies. *International Journal of Production Research*, 1–18. <https://doi.org/10.1080/00207543.2021.1966850>

Eslami, M. H., Jafari, H., Achtenhagen, L., Carlbäck, J., & Wong, A. C. (2021b). Financial performance and supply chain dynamic capabilities: the Moderating Role of Industry 4.0 technologies. *International Journal of Production Research*, 1–18. <https://doi.org/10.1080/00207543.2021.1966850>

FA. (2023). Ford Blockchain Initiative Aims To Identify Unethically Sourced. Retrieved from <https://fordauthority.com/2021/12/ford-blockchain-initiative-aims-to-identify-unethically-sourced-materials/#:~:text=The%20Ford%20blockchain%20initiative%20will,EV%20battery%20supplies%20are%20sourced.>

FANUC . (2022). FANUC to supply Ford plant in Cologne with 500 robots. Retrieved from <https://www.fanuc.eu/ua/en/who-we-are/news/de-fanuc-automatisierungsspezialist-06-2021>

Fatorachian, H., & Kazemi, H. (2020). Impact of Industry 4.0 on supply chain performance. *Production Planning & Control*, 32(1), 63–81. <https://doi.org/10.1080/09537287.2020.1712487>

Fatorachian, H., & Kazemi, H. (2020b). Impact of Industry 4.0 on supply chain performance. *Production Planning & Control*, 32(1), 63–81. <https://doi.org/10.1080/09537287.2020.1712487>

Fatorachian, H., & Kazemi, H. (2020c). Impact of Industry 4.0 on supply chain performance. *Production Planning & Control*, 32(1), 63–81. <https://doi.org/10.1080/09537287.2020.1712487>

Ferdows, K. (2022). Rapid-Fire Fulfillment. Retrieved from <https://hbr.org/2004/11/rapid-fire-fulfillment>

Forbes. (2022). 3 Must-Haves For Intelligent Manufacturing. Retrieved from <https://www.forbes.com/sites/samsungsds/2020/01/06/3-must-haves-for-intelligent-manufacturing/?sh=4dcc1126670e>

Ford . (2023). Ford Motor Enters Digital Era With Its Advanced Manufacturing Center. Retrieved from <https://connectedmanufacturing.wbresearch.com/blog/ford-motor-company-advanced-manufacturing-center-strategy>

Ford. (2023). Go Further: Better World. Retrieved from <https://www.india.ford.com/about-ford/community/csr/>

Fretty, P. (2020). 2020 Manufacturing Technology Leader of the Year: Ford's Gary Johnson. Retrieved from <https://www.industryweek.com/technology-and-iiot/article/21150030/2020-manufacturing-technology-leader-of-the-year-fords-gary-johnson>

Ghadge, A., Kara, M. E., Moradlou, H., & Goswami, M. (2020b). The impact of Industry 4.0 implementation on supply chains. *Journal of Manufacturing Technology Management*, 31(4), 669–686. <https://doi.org/10.1108/jmtm-10-2019-0368>

GSMA. (2022). Ford and Vodafone harness private 5G networks to continually optimise vehicle manufacturing. Retrieved from <https://www.gsma.com/iot/wp->

content/uploads/2021/05/2021-05-GSMA-5G-IoT-for-Manufacturing-Case-Study-Ford-and-Vodafone.pdf

Gupta, S., Modgil, S., Meissonier, R., & Dwivedi, Y. K. (2022). Artificial intelligence and information system resilience to cope with supply chain disruption. *IEEE Transactions on Engineering Management*, 1–11. <https://doi.org/10.1109/tem.2021.3116770>

Hallikas, J., Immonen, M., & Brax, S. (2021). Digitalizing procurement: the impact of data analytics on supply chain performance. *Supply Chain Management*, 26(5), 629–646. <https://doi.org/10.1108/scm-05-2020-0201>

Ho, W. R., Tsolakis, N., Daves, T., Dora, M., & Kumar, M. (2023c). A Digital Strategy Development Framework for supply chains. *IEEE Transactions on Engineering Management*, 70(7), 2493–2506. <https://doi.org/10.1109/tem.2021.3131605>

Hofmann, E., Sternberg, H., Chen, H., Pflaum, A., & Prockl, G. (2019b). Supply chain management and Industry 4.0: conducting research in the digital age. *International Journal of Physical Distribution & Logistics Management*, 49(10), 945–955. <https://doi.org/10.1108/ijpdlm-11-2019-399>

Huang, H., Zhang, J., Ren, X., & Zhou, X. (2018). Greenness and pricing decisions of cooperative supply chains considering altruistic preferences. *International Journal of Environmental Research and Public Health*, 16(1), 51. <https://doi.org/10.3390/ijerph16010051>

Huang, L., Han, Y., Yuan, A., Xiao, T., Wang, L., Yu, Y., Zhang, X., Zhan, H., & Zhu, H. (2022). New business form of smart supply chain management based on “Internet of Things + Blockchain.” *Mobile Information Systems*, 2022, 1–8. <https://doi.org/10.1155/2022/1724029>

Humdan, E. A. (2020). Supply chain agility: a systematic review of definitions, enablers and performance implications. *International Journal of Physical Distribution & Logistics Management ahead-of-print(ahead-of-print)*.

Hwang, C. (2022). Samsung's ups and downs (2): A reexamination of Samsung's biz structure from a Taiwanese perspective. Retrieved from <https://www.digitimes.com/news/a20220913VL205/foundry-handset-memory-chips-samsung.html>

Islam, M. R. (2023). Supply Chain Management and Logistics: How Important Interconnection Is for Business Success. *Open Journal of Business and Management*, 11(5).

Ivanov, D., & Dolgui, A. (2020). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control*, 32(9), 775–788. <https://doi.org/10.1080/09537287.2020.1768450>

Ivanovska, L. P., Josimovski, S., & Nestoroska, M. (2021b). IMPLICATIONS OF COVID-19 CRISIS ON SUPPLY CHAIN MANAGEMENT. *Journal of Sustainable Development*, 12(27), 3–14. <https://doi.org/10.54442/jsd21122703pi>

JA. (2020). Wrist smartphone speeds Ford quality checks. Retrieved from <https://www.just-auto.com/news/wrist-smartphone-speeds-ford-quality-checks/>

Järvensivu, T., & Törnroos, J. (2010b). Case study research with moderate constructionism: Conceptualization and practical illustration. *Industrial Marketing Management*, 39(1), 100–108. <https://doi.org/10.1016/j.indmarman.2008.05.005>

Jiang, W., Jiang, F., Zhang, Z., & Chen, Z. (2023). Study on Digital Technology Collaboration Strategy of Supply Chain Enterprises Based on Evolutionary Game. *Study on Digital Technology Collaboration Strategy of Supply Chain Enterprises Based on Evolutionary Game*. <https://doi.org/10.4108/eai.9-12-2022.2327699>

John. (2024). 11 Key Points In Pepsi-Cola Supply Chain Management. Retrieved from <https://www.linkedin.com/pulse/11-key-points-pepsi-cola-supply-chain-management-john-l--rdhjc/>

Katsikouli, P., Wilde, A. S., Dragoni, N., & Høgh-Jensen, H. (2020). On the benefits and challenges of blockchains for managing food supply chains. *Journal of the Science of Food and Agriculture*, 101(6), 2175–2181. <https://doi.org/10.1002/jsfa.10883>

Ketchen, D. J., & Hult, G. T. M. (2006). Bridging organization theory and supply chain management: The case of best value supply chains. *Journal of Operations Management*, 25(2), 573–580. <https://doi.org/10.1016/j.jom.2006.05.010>

Khamseh, A., Lialestani, M. a. M., & Radfar, R. (2021). Digital Transformation model, based on grounded theory. *Journal of Information Systems and Telecommunication*, 9(36), 275–284. <https://doi.org/10.52547/jist.9.36.275>

Kim, M., & Chai, S. (2016). Assessing the impact of business uncertainty on supply chain integration. *The International Journal of Logistics Management*, 27(2), 463–485. <https://doi.org/10.1108/ijlm-11-2014-0175>

Kim, S. (2022). Samsung Blockchain. Retrieved from <https://tech.hindustantimes.com/tech/news/samsung-joins-blockchain-bandwagon-to-manage-its-supply-chain-story-xRwYv68ucTwDoasNErDd2K.html>

Kim, S. T. (2020). Logistics integration in the supply chain: a resource dependence theory perspective. *International Journal of Quality Innovation* .

Klar, R., Fredriksson, A., & Angelakis, V. (2023). Digital twins for ports: derived from smart city and supply chain twinning experience.. <https://doi.org/10.48550/arxiv.2301.10224>

Kleindorfer, P. R., & Saad, G. H. (2005). Managing disruption risks in supply chains. *Production and Operations Management*, 14(1), 53–68. <https://doi.org/10.1111/j.1937-5956.2005.tb00009.x>

Knight, W. (2021). Ford's Ever-Smarter Robots Are Speeding Up the Assembly Line. Retrieved from <https://www.wired.com/story/fords-smarter-robots-speeding-assembly-line/>

Kour, B. (2021). Samsung Integrates Blockchain into Their Business Model. Retrieved from <https://appinventiv.com/blog/samsung-integrates-blockchain-in-business-model/>

Kozhanov, N. and Woebbeking, F. (2021). Some aspects of using blockchain in supply chain management in the framework of achieving sustainable development goals. *E3S Web of Conferences*, 296, 06012. <https://doi.org/10.1051/e3sconf/202129606012>

Kshetri, N. (2018b). 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*, 39, 80–89. <https://doi.org/10.1016/j.ijinfomgt.2017.12.005>

Lauzier, J. (2021). MANUFACTURING TOOLING COSTS - A COMPLETE GUIDE. Retrieved from <https://www.machinemetrics.com/blog/tooling-costs>

Leung, T. (2022). Digitalization in the Real-World, Part 2. Retrieved from <https://blog.blueyonder.com/digitalization-in-the-real-world-part-2/>

Lezoche, M., Hernández, J. E., Ruiz, L. P., Panetto, H., & Kacprzyk, J. (2020). Agri-food 4.0: A survey of the supply chains and technologies for the future agriculture. *Computers in Industry*, 117, 103187. <https://doi.org/10.1016/j.compind.2020.103187>

Li, Y., & Chen, T. (2022). Blockchain empowers supply chains: challenges, opportunities and prospects. *Nankai Business Review International*, 14(2), 230–248. <https://doi.org/10.1108/nbri-06-2022-0066>

Liang, X., Xie, Z., & Li, S. (2023). The impact of supply chain management on the digital transformation of Chinese manufacturing enterprises. In *2022 2nd International Conference on Management Science and Software Engineering (ICMSSE 2022)* (pp. 860–866). https://doi.org/10.2991/978-94-6463-056-5_124

Loeb, W. (2023). Zara's 30% Expansion And 2022 Outstanding Results. Retrieved from <https://www.forbes.com/sites/walterloeb/2023/03/22/zaras-30-expansion-and-2022-outstanding-results/?sh=1f89919c24a5>

Lugada, E., Komakech, H., Ochola, I., Mwebaze, S., Oteba, M. O., & Ladwar, D. O. (2022). Health supply chain system in Uganda: current issues, structure, performance, and implications for systems strengthening. *Journal of Pharmaceutical Policy and Practice*, 15(1). <https://doi.org/10.1186/s40545-022-00412-4>

Magoulick, J. (2019). Ford's Use of AI an Example of Shaping Innovation in MIT Future of Work Session. Retrieved from <https://internetofbusiness.com/fords-use-of-ai-an-example-of-shaping-innovation-in-mit-future-of-work-session/>

Mak, H., & Shen, Z. M. (2020). When Triple-A supply chains meet digitalization: the case of JD.Com's C2M model. *Production and Operations Management*, 30(3), 656–665. <https://doi.org/10.1111/poms.13307>

Marr, B. (2019). The Fascinating Ways PepsiCo Uses Artificial Intelligence And Machine Learning To Deliver Success. Retrieved from <https://www.forbes.com/sites/bernardmarr/2019/04/05/the-fascinating-ways-pepsico-uses-artificial-intelligence-and-machine-learning-to-deliver-success/?sh=6d970217311e>

Mathas, C. (2021). Supply Chains—From Henry Ford to Artificial Intelligence. Retrieved from <https://partprocurer.com/supply-chains-from-henry-ford-to-artificial-intelligence/>

MC. (2023). Data Analytics & AI/ML Use Case. Retrieved from https://www.megazone.com/us/aiml_samsungelectronics/

Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). DEFINING SUPPLY CHAIN MANAGEMENT. *Journal of Business Logistics*, 22(2), 1–25. <https://doi.org/10.1002/j.2158-1592.2001.tb00001.x>

MFG3D. (2022). Case Study: How PepsiCo achieved 96% cost savings on tooling with 3D Printing Technology. Retrieved from <https://manufactur3dmag.com/case-study-pepsico-tooling-with-3d-printing-technology/>

Mhugos. (2023). Zara Clothing Company Supply Chain. Retrieved from <https://www.scmglobe.com/zara-clothing-company-supply-chain/#:~:text=Zara's%20factories%20can%20quickly%20increase,90%20percent%20done%20by%20competitors.>

Mickelson, P. (2018). Efficiencies through digitalization of supply chain at Inditex. Retrieved from [Efficiencies through digitalization of supply chain at Inditex](#)

Modgil, S., Singh, R., & Hannibal, C. (2021b). Artificial intelligence for supply chain resilience: learning from Covid-19. *The International Journal of Logistics Management*, 33(4), 1246–1268. <https://doi.org/10.1108/ijlm-02-2021-0094>

Montecchi, M. (2021). Supply chain transparency: A bibliometric review and research agenda. *International Journal of Production Economics*.

Morgan, B. (2019). Companies That Failed At Digital Transformation And What We Can Learn From Them. Retrieved from <https://www.forbes.com/sites/blakemorgan/2019/09/30/companies-that-failed-at-digital-transformation-and-what-we-can-learn-from-them/?sh=21fb0289603c>

Mouncer, B. (2023). Samsung eyes blockchain technology to cut supply chain costs by 20%. Retrieved from <https://supplychaindigital.com/technology/samsung-eyes-blockchain-technology-cut-supply-chain-costs-20>

MR. (2022). The Secret of Zara's Success: A Culture of Customer Co-creation. Retrieved from <https://martinroll.com/resources/articles/strategy/the-secret-of-zaras-success-a-culture-of-customer-co-creation/>

Mubarik, M. S., Khan, S. A., Acquaye, A., & Mubarik, M. (2023). Supply chain mapping for improving “visilience”: A hybrid multi-criteria decision making based

methodology. *Journal of Multi-Criteria Decision Analysis*, 30(5–6), 173–189. <https://doi.org/10.1002/mcda.1807>

Mukhamedjanova, K. A. (2020). CONCEPT OF SUPPLY CHAIN MANAGEMENT. *Journal of Critical Reviews*, 7(02). <https://doi.org/10.31838/jcr.07.02.139>

Mullan, L. (2023). Ford pushes for supply chain transparency in cobalt mining using IBM blockchain technology. Retrieved from <https://technologymagazine.com/data-and-data-analytics/ford-pushes-supply-chain-transparency-cobalt-mining-using-ibm-blockchain-technology>

Nagpal, G. (2023). Digitalize or perish — a new norm in supply chains. Retrieved from <https://retail.economictimes.indiatimes.com/blog/digitalize-or-perish-a-new-norm-in-supply-chains/98802451#:~:text=Similarly%2C%20Zara%2C%20a%20fashion%20industry,make%2Dto%2Ddesign%20products.>

Nguyễn, X. H., Doan, T. D. U., & Van Ngoc, H. (2020). The impact of global supply chain management on performance: Evidence from Textile and garment industry. *Uncertain Supply Chain Management*, 17–26. <https://doi.org/10.5267/j.uscm.2019.9.003>

Ni, S., Peng, Y., Peng, K., & Liu, Z. (2022b). Supply chain demand Forecast based on SSA-XGBOOST model. *Journal of Computer and Communications*, 10(12), 71–83. <https://doi.org/10.4236/jcc.2022.1012006>

Nozari, H., Szmelter-Jarosz, A., & Ghahremani-Nahr, J. (2022). Analysis of the Challenges of Artificial Intelligence of Things (AIOT) for the smart supply chain (Case Study: FMCG Industries). *Sensors*, 22(8), 2931. <https://doi.org/10.3390/s22082931>

Olan, F., Arakpogun, E. O., Jayawickrama, U., Suklan, J., & Liu, S. (2022). Sustainable supply chain finance and supply networks: The role of Artificial intelligence. *IEEE Transactions on Engineering Management*, 1–16. <https://doi.org/10.1109/tem.2021.3133104>

OPTOMECH. (2022). Optomech helps make consumer and industrial devices smart and connected with 3D Printed sensors and antennas for Internet of Things applications. Retrieved from <https://optomech.com/printed-electronics/aerosol-jet-core-applications/internet-of-things/>

Park, A., & Li, H. (2021b). The effect of blockchain technology on supply chain sustainability performances. *Sustainability*, 13(4), 1726. <https://doi.org/10.3390/su13041726>

Paul, S. K., & Chowdhury, P. (2020). A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19. *International Journal of Physical Distribution & Logistics Management*, 51(2), 104–125. <https://doi.org/10.1108/ijpdIm-04-2020-0127>

Paulraj, A., Chen, I. J., & Lado, A. A. (2012). An Empirical Taxonomy of Supply chain Management Practices. *Journal of Business Logistics*, 33(3), 227–244. <https://doi.org/10.1111/j.0000-0000.2012.01046.x>

PepsiCo. (2022). We're using our global scale and reach to spark joy and create more smiles. Retrieved from <https://www.pepsico.com/who-we-are/about-pepsico#:~:text=Global%20Leader%20in%20Convenient%20Foods,and%20territories%20around%20the%20world>.

Pizzichini, L., Temperini, V., Caboni, F., & Papa, A. (2023). The role of digital knowledge servitization in supply chain management. *International Journal of Physical Distribution & Logistics Management*, 53(5/6), 589–611. <https://doi.org/10.1108/ijpdIm-06-2022-0202>

Pyun, J., & Rha, J. S. (2021c). Review of Research on Digital Supply Chain Management using Network Text Analysis. *Sustainability*, 13(17), 9929. <https://doi.org/10.3390/su13179929>

Qrunfleh, S., & Tarafdar, M. (2013). Lean and agile supply chain strategies and supply chain responsiveness: the role of strategic supplier partnership and postponement. *Supply Chain Management*, 18(6), 571–582. <https://doi.org/10.1108/scm-01-2013-0015>

Rahamneh, A. a. A., Alrawashdeh, S. T., Bawaneh, A. A., Alatyat, Z. A., Mohammad, A., Mohammad, A. a. S., & Al-Hawary, S. I. S. (2023b). The effect of digital supply chain on lean manufacturing: A structural equation modelling approach. *Uncertain Supply Chain Management*, 11(1), 391–402. <https://doi.org/10.5267/j.uscm.2022.9.003>

Rahamneh, A. a. A., Alrawashdeh, S. T., Bawaneh, A. A., Alatyat, Z. A., Mohammad, A., Mohammad, A. a. S., & Al-Hawary, S. I. S. (2023c). The effect of digital supply chain on lean manufacturing: A structural equation modelling

approach. *Uncertain Supply Chain Management*, 11(1), 391–402.
<https://doi.org/10.5267/j.uscm.2022.9.003>

Rahamneh, A. a. A., Alrawashdeh, S. T., Bawaneh, A. A., Alatyat, Z. A., Mohammad, A., Mohammad, A. a. S., & Al-Hawary, S. I. S. (2023d). The effect of digital supply chain on lean manufacturing: A structural equation modelling approach. *Uncertain Supply Chain Management*, 11(1), 391–402.
<https://doi.org/10.5267/j.uscm.2022.9.003>

Raza, Z., Haq, I. U., & Muneeb, M. (2023). Agri-4-ALL: A framework for blockchain based agricultural food supply chains in the era of Fourth Industrial Revolution. *IEEE Access*, 11, 29851–29867. <https://doi.org/10.1109/access.2023.3259962>

RH. (2023). Ford Otosan achieves 3% savings using predictive digital twins . Retrieved from <https://www.royalhaskoningdhv.com/en/twinn/impact-stories/ford-otosan-and-predictive-digital-twins>

Rishi, P. (2023). Navigating Post-Pandemic Challenges: Unlocking Profitability Through Inventory Optimization in Fashion and Beauty Industry. Retrieved from *Navigating Post-Pandemic Challenges: Unlocking Profitability Through Inventory Optimization in Fashion and Beauty Industry*.

Roberts, B. (2023). ‘Zara Meets Netflix’—The Fashion House Where AI Removes Designers And Overstock. Retrieved from <https://www.forbes.com/sites/brookeroberthislam/2021/01/27/zara-meets-netflix-the-fashion-house-where-ai-replaces-designers-eliminating-overstock/?sh=73132d0433ed>

Rogers, H., Baricz, N., & Pawar, K. S. (2016). 3D Printing Services: Classification, supply chain implications and research agenda. *International Journal of Physical Distribution & Logistics Management*, 46(10), 886–907.
<https://doi.org/10.1108/ijpdIm-07-2016-0210>

Rosenbaum, E. (2023). There’s a ‘deep misunderstanding’ about AI and job losses that has the Department of Labor’s attention. Retrieved from <https://www.cnbc.com/2023/12/06/a-deep-misunderstanding-about-ai-is-a-big-risk-to-workers-biden-labor-secretary.html>

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. Y. (2018b). Blockchain technology and its relationships to sustainable supply chain management.

International Journal of Production Research, 57(7), 2117–2135.
<https://doi.org/10.1080/00207543.2018.1533261>

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. Y. (2018d). Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research, 57(7), 2117–2135.
<https://doi.org/10.1080/00207543.2018.1533261>

Salsas, J. G., Saurí, S., Raventós, E., Rúa, C., & Torrent, J. (2021). Emerging Trends defining the future role of ports: Application of the Delphi Method. Transportation Research Record, 2676(3), 571–585.
<https://doi.org/10.1177/03611981211052962>

Sani, S., Schaefer, D., & Milisavljevic-Syed, J. (2022). Utilising digital twins for increasing military supply chain visibility. In Advances in transdisciplinary engineering. <https://doi.org/10.3233/atde220595>

Sasson, A., & Johnson, J. C. (2016b). The 3D printing order: variability, supercenters and supply chain reconfigurations. International Journal of Physical Distribution & Logistics Management, 46(1), 82–94. <https://doi.org/10.1108/ijpdlm-10-2015-0257>

Schäfer, N. (2023). Making transparency transparent: a systematic literature review to define and frame supply chain transparency in the context of sustainability. pages579–604.

Seemsay. (2021). How 3D Fashion Design Technology Saves Your Time. Retrieved from <https://medium.com/@seemsay/how-3d-fashion-design-technology-saves-your-time-bba81f118d81>

Selviaridis, K., & Norrman, A. (2014). Performance-based contracting in service supply chains: a service provider risk perspective. Supply Chain Management, 19(2), 153–172. <https://doi.org/10.1108/scm-06-2013-0216>

Seyedghorban, Z., Samson, D., & Tahernejad, H. (2020). Digitalization opportunities for the procurement function: pathways to maturity. International Journal of Operations & Production Management, 40(11), 1685–1693.
<https://doi.org/10.1108/ijopm-04-2020-0214>

SGN. (2022). Samsung Begins Chip Production Using 3nm Process Technology With GAA Architecture. Retrieved from <https://news.samsung.com/global/samsung-begins-chip-production-using-3nm->

process-technology-with-gaa-architecture#:~:text=Compared%20to%205nm%20process%2C%20the,and%20reduce%20area%20by%2035%25.

Shi, Y., Ying, J., Shi, D., & Yan, J. (2022b). Service-Oriented modeling for Blockchain-Enabled supply chain quality information systems. *Security and Communication Networks*, 2022, 1–16. <https://doi.org/10.1155/2022/1987933>

Statista. (2022). E-Commerce net sales of zara.com from 2014 to 2022. Retrieved from <https://www.statista.com/forecasts/1218316/zara-revenue-development-ecommercedb>

Statista. (2022). Ford's revenue from FY 2008 to FY 2022(in billion U.S. dollars). Retrieved from <https://www.statista.com/statistics/267305/total-revenue-of-ford/#:~:text=The%20Ford%20Motor%20Company%20reported,4.2%20million%20units%20in%202022.>

Statista. (2022). PepsiCo's net revenue worldwide from 2007 to 2022. Retrieved from <https://www.statista.com/statistics/233378/net-revenue-of-pepsico-worldwide/#:~:text=In%202022%2C%20PepsiCo's%20net%20revenue,about%20086.39%20billion%20U.S.%20dollars.&text=PepsiCo%20is%20an%20American%20food,%2C%20based%20in%20Purchase%2C%20NY.>

Statista. (2022). Samsung Electronics' global revenue from 2005 to 2022. Retrieved from [https://statista.com/statistics/236607/global-revenue-of-samsung-electronics-since-2005/#:~:text=The%20global%20revenue%20made%20by,approximately%20234.08%20billion%20U.S.%20dollars\).](https://statista.com/statistics/236607/global-revenue-of-samsung-electronics-since-2005/#:~:text=The%20global%20revenue%20made%20by,approximately%20234.08%20billion%20U.S.%20dollars).)

Tableau. (2022). How PepsiCo tamed big data and cut analysis time by 70%. Retrieved from <https://www.tableau.com/blog/how-pepsico-tamed-big-data-and-cut-analysis-time-70-59205>

Tang, Q., Wu, B., Chen, W., & Jinyue, Y. (2023). A digital Twin-Assisted Collaborative Capability optimization model for smart manufacturing system based on Elman-IVIF-TOPSIS. *IEEE Access*, 11, 40540–40564. <https://doi.org/10.1109/access.2023.3269577>

Temjanovski, R. and Dimitrova, J. (2023). Supply chain mapping as advanced business model. *Journal of Economics*, 8(1), 45-54. <https://doi.org/10.46763/joe2381045t>

Towers, N. (2001). The supply chain management of production planning and sustainable customer relationships. *Management Research News*, 24(12).

Uberoi, R. (2018). ZARA: Achieving the “Fast” in Fast Fashion through Analytics. Retrieved from <https://d3.harvard.edu/platform-digit/submission/zara-achieving-the-fast-in-fast-fashion-through-analytics/>

Vanpoucke, E., Vereecke, A., & Muylle, S. (2017). Leveraging the impact of supply chain integration through information technology. *International Journal of Operations & Production Management*, 37(4), 510–530. <https://doi.org/10.1108/ijopm-07-2015-0441>

Varma, S. P., Singh, N., & Zhang, Z. (2023). Evolving trajectories of circular supply chain domain: a citation path analysis. *Journal of Enterprise Information Management*, 36(6), 1610–1646. <https://doi.org/10.1108/jeim-03-2023-0147>

Viale, L. and Zouari, D. (2020). Impact of digitalization on procurement: the case of robotic process automation. *Supply Chain Forum: An International Journal*, 21(3), 185-195. <https://doi.org/10.1080/16258312.2020.1776089>

Wang, Y., Han, J. W., & Beynon-Davies, P. (2019). Understanding blockchain technology for future supply chains: a systematic literature review and research agenda. *Supply Chain Management*, 24(1), 62–84. <https://doi.org/10.1108/scm-03-2018-0148>

Wu, L., Yue, X., Jin, A., & Yen, D. C. (2016). Smart supply chain management: a review and implications for future research. *The International Journal of Logistics Management*, 27(2), 395–417. <https://doi.org/10.1108/ijlm-02-2014-0035>

Xiao, X., Dou, J., & Shang, Y. (2020). Blockchain-driven supply chain decentralized operations – information sharing perspective. *Business Process Management Journal*, 27(1), 184–203. <https://doi.org/10.1108/bpmj-12-2019-0518>

Yang, M., Fu, M., & Zhang, Z. (2021b). The adoption of digital technologies in supply chains: Drivers, process and impact. *Technological Forecasting and Social Change*, 169, 120795. <https://doi.org/10.1016/j.techfore.2021.120795>

Zhao, X., Xie, J., & Lau, R. S. M. (2001b). Improving the supply chain performance: Use of forecasting models versus early order commitments. *International Journal of Production Research*, 39(17), 3923–3939. <https://doi.org/10.1080/00207540110072236>

Zhou, S. (2020). How Augmented Reality Transform the Customer Experience? Retrieved from <https://medium.com/marketing-in-the-age-of-digital/how-augmented-reality-transform-the-customer-experience-cf96391639c9>

Zipfela, A. (2019). Approach for a Production Planning and Control System. 1195–1200.

Mukhamedjanova, K. A. (2020a). CONCEPT OF SUPPLY CHAIN MANAGEMENT. *Journal of Critical Reviews*, 7(02). <https://doi.org/10.31838/jcr.07.02.139>

Pettit, T. J., Croxton, K. L., & Fiksel, J. (2013). Ensuring supply chain resilience: Development and implementation of an assessment tool. *Journal of Business Logistics*, 34(1), 46–76. <https://doi.org/10.1111/jbl.12009>

Hofmann, E., Sternberg, H., Chen, H., Pflaum, A., & Prockl, G. (2019a). Supply chain management and Industry 4.0: conducting research in the digital age. *IJPDLM*, 49(10), 945–955. <https://doi.org/10.1108/ijpdIm-11-2019-399>

Mangla, S. K., Govindan, K., & Luthra, S. (2017). Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy Analytical Hierarchy Process. *Journal of Cleaner Production*, 151, 509–525. <https://doi.org/10.1016/j.jclepro.2017.02.099>

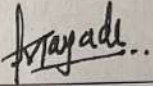
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