

Navigating Digitalisation in Supply Chain Management: Challenges and Opportunities in the Modern Era

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ABSTRACT

Digitalisation of Supply Chain Management (SCM) has emerged as a force of transformation, redefining conventional processes with the help of technologies such as the Internet of Things (IoT), AI, and blockchain. This paper explores the dual nature of digitalisation in SCM: the great opportunities it affords, such as enhanced operational efficiency, sustainability, and risk mitigation, but also several challenges, ranging from high implementation costs to integration complexities and resistance to change. Based on the quantitative survey of 204 SCM professionals, this research identifies the main drivers toward digitalisation, evaluates the consequences of digitalisation on operational outcomes, and stresses technology adoption as being crucial in improving transparency, collaboration, and resilience. The findings presented will provide actionable insights into how organisations can strategically align their digital transformation with sustainability objectives while enhancing the competitive advantage. Future research directions include the examination of emerging technologies such as quantum computing and industry-specific digitalisation impacts.

Keywords: Supply Chain Management (SCM), Digitalisation, Internet of Things (IoT), AI (Artificial Intelligence), Blockchain, Sustainability, Operational Efficiency, Risk Mitigation, Digital Transformation, Supply Chain Resilience

Introduction

Digitalisation in Supply Chain Management (SCM) represents a transformative change that integrates advanced technologies into traditional supply chain processes, thereby enhancing efficiency, visibility, and responsiveness (Lukina et al., 2023). Often associated with the broader paradigm of Industry 4.0, this transformation plays a crucial role in enabling organisations to operate effectively in the increasingly complex and interconnected global market (Saber et al., 2018). Growing demands for operational performance, the coming age of automation, and internally changing buyer behaviour oblige organisations to embed digitalisation into their strategic SCM frameworks (Seyedan & Mafakheri 2020). Indeed, digital solutions can enable organisations to automate their processes, resulting in reduced operational costs, increased agility, and enhanced competitive positioning, particularly in a volatile market environment. These include automation, IoT, AI, blockchain, and predictive analytics, each contributing their unique value proposition

to enhance the resilience and agility of the supply chain (Pflaum et al., 2021). On the contrary, while digitalisation presents tremendous opportunities, the adoption of new operating models and technical infrastructure challenges the adaptability of traditional SCM frameworks (Aamer et al., 2022).

In this regard, digitalisation has been transforming SCM over the last decade, presenting numerous challenges and opportunities that shape organisations' operational strategies (Kache & Seuring 2017). The first most obvious challenge pertains to how new digital technologies should be integrated into already existing, often legacy systems (Aziz, 2021). Most organisations are still concerned with substantial investments in technology and human resources for the successful execution of IoT, AI, blockchain, and advanced analytics (Pyun & Rha, 2021). Such investments are heavy and can result in resource strain and disruption of operations if strategically not well planned (Ivanov et al., 2018). Moreover, the vagueness of ideas surrounding digitalisation complicates its implementation, making it difficult to determine which digitisation strategies or

goals align best with an organisation's overall business objectives (Shi et al., 2022). If anything, this may be hindered by simple digital ignorance within organisations, whose employees may need intensive training to manage and maintain such technologies.

On the other hand, digitalisation is also creating enormous opportunities that test the resilience and performance of the supply chain. For instance, analytics capabilities provided by digital tools could allow a revolutionary forecast and decision-making process through far better resource allocation, proactive risk management, or seeing "around the corner" of the supply chain (Zhou et al., 2023). Predictive analytics may, then, allow firms to foresee well in advance problems that will occur and thus prepare for them and react before their impact on operations is felt (Garay-Rondero et al. 2019). Moreover, the digital platforms allow for greater collaboration between supply chain partners, leading to an integrated approach toward SCM, something quite essential when the markets are turbulent and for which agility and quick response becomes very significant in terms of competitive advantage (Kuteyi & Winkler, 2022). Therefore, an organisation that leverages digitalisation to establish stronger relationships through improved communication, prompt response, and operational flexibility will be better equipped to adapt to market changes and disruptions (Moosavi et al., 2021).

These findings are therefore useful and contribute to better insights for industry stakeholders, policymakers, and practitioners. Since digital transformation keeps reshaping SCM, understanding its dynamics becomes crucial in the development of industry standards and best practices toward efficiency, sustainability, and resilience in supply chains (Park & Li, 2021). From an industrial perspective, it will allow organisations to refine their operational strategy by effectively utilising digital technologies and minimising associated risks. This would ultimately contribute positively to an improvement in performance and competitive positions (Menon & Shah, 2019). Policymaking authorities will also gain valuable insights into digitally induced changes in regulatory frameworks along with policies meant for fostering innovation and competitive behaviour in the industry. Other rather similar views have been put forward (Herold et al., 2021) on the same aspect. These supportive policies, which address barriers to technology adoption such as workforce skills shortages and data security concerns, would create more

avenues toward building supply chain resilience.

- This study's main goal is to continue in-depth studies on digitalisation in supply chain management, keeping in mind that new opportunities and challenges as a multifaceted phenomenon will affect how businesses work and what policies are in place. Concretely, this research aims to
- Investigate the multifaceted nature of digitalisation in SCM: how IoT, AI, and blockchain reshape traditional supply chain processes for a connected, data-driven operational model.
- Identify the challenges and opportunities that digitalisation brings about. Specifically, it is crucial to identify complex issues such as the integration of technologies, investment in resources, and skill development.
- Evaluate the practical relevance of digitalisation in SCM, discussing implications for operational strategies and performance outcomes and its relevance for industry standards and policy frameworks.

Literature Review

Digitalisation in Supply Chain Management

One of the main trends that this digitisation process of supply chains shows is expressed by the increasing visibility and transparency of IoT technologies. From this point on, the implementation of IoT enables an organisation to gather data from inventory levels and shipment tracking points, which it can then share in real-time with each stage of the value chain, resulting in more accurate predictions of demand fluctuations (Pflaum et al., 2021; Pyun & Rha, 2021). Enhanced visibility will further support business operations, enhancing operability and enabling timely decision-making to respond to market changes and disruptions (Aamer et al., 2022). Hence, the literature suggests that the deep integration of digital technologies into supply chain processes allows fundamental changes that address key management problems to result in an agile supply chain environment (Quan et al., 2023).

AI plays a pivotal role in enhancing supply chain operations by allowing advanced analytics and predictive modelling. The organisation uses AI to enhance forecast

accuracy, streamline logistics, or developing better methods of selecting suppliers (Pyun & Rha, 2021; Sharma, 2018). For instance, several data elements analysed by AI algorithms develop patterns and trends, allowing planners to improve demand planning and inventory management (Aamer et al., 2022). AI also enables better risk management by predicting disruptions that may happen and, therefore, taking remedial steps proactively (Aziz, 2021). It has been widely recognised that AI has a vital role in supply management and is considered to be very critical in achieving a competitive advantage in the digital era (Jiang et al., 2023).

It has been a transformative force in SCM for the integration of trust and safety among the partners within the chain. It assists blockchain-based supply chains in providing transparency over transactions and traceability of their merchandise, recorded on an open, decentralised, untouched ledger (Mubarik et al., 2021; Tran & Trinh, 2021). This technology thus finds significant applications in industries dependent on provenance and authenticity, such as pharmaceuticals and food safety (Qian & Papadonikolaki, 2020). Each of these is supported by the literature, which says blockchain will significantly reduce fraud, increase compliance, and raise the overall efficiency of supply chains through either automation or a reduced need to go through intermediaries (Rauniyar et al., 2022). However, organisations must overcome challenges related to scalability and integration with existing systems to fully reap the benefits of the blockchain (Mathivathanan et al., 2021).

Digitalisation can also be closely linked to sustainability initiatives in supply chains. The adoption of Industry 4.0 technologies, IoT and blockchain, for example, facilitates green supply chain practices through enhanced resource efficiency and reduced waste (Mubarik et al., 2021; Herold et al., 2021). Real-time monitoring, facilitated by IoT, for instance, helps an organisation optimise its energy consumption and thereby reduces its carbon footprint accordingly (Pyun & Rha, 2021). Thus, the crossroads of digitalisation and sustainability have been set in firm concrete as a key area for future research in which organisations balance operational efficiency against environmental responsibility (Aziz, 2021).

After discussing the impact brought into supply chain operations by the emergence of digital tools like IoT, AI, and blockchain, we hypothesise the following:

Hypothesis 1: Digitalisation positively impacts supply chain performance by improving transparency, operational efficiency, and risk management.

Challenges of Digitalisation

This inherent power of resistance provided to employees and management for change is the key barrier to digitisation within supply chains. Often, this resistance stems from factors such as fear of the unknown, concerns about job security, and misconceptions about the true benefits that digital technologies can offer (Vass et al., 2021). Employees generally expect traditional processes and may consider the new technologies as disruptions rather than using them to improve. For instance, a case study revealed that in any supply chain setting, stakeholders' reluctance to share data can impede the adoption of IoT solutions. Moreover, the shift in culture toward a more digital format necessitates serious approaches to change management, such as training and communication with individuals to foster an open culture (Heeres, 2023).

The other big stumbling block is caused by technological integration. Interoperability issues arise when new digital technologies are integrated with existing systems (Aamer et al., 2021; Udeh, 2024). Such is the case when IoT devices are integrated with legacy systems, which are burdensome and costly and hence carry huge capital investment and continuous maintenance, as evidenced by Aamer et al. (2021). Secondly, the absence of coherent protocols across diverse technologies raises complications of integration, thereby making the data more fragmented and operations ineffective (Mashat, 2024; Luthra & Mangla, 2018). As organisations strive to automate their supply chain processes, responding to these challenges of integration will be the only way that seamless flow across diverse platforms can be certified.

Supply chains become increasingly vulnerable to cyber threats the more integrated they are with digitalisation. This is because the interconnected nature of digitalisation makes any breach in one part of the network trigger cascading effects across the entire network (Adeusi, 2024; Malik et al., 2019). Data security concerns are paramount, as sensitive information on shared platforms serves as a potential target for malicious actors (Udeh, 2024). While the use of IoT devices and blockchain

technology offers significant benefits such as increased transparency and traceability, it also introduces additional vulnerabilities that each organisation must address (Hasan et al., 2023; Hussain et al., 2021). Important cybersecurity measures include encryption, stringent access controls, and continuous operation monitoring to maintain trust requirements with partner companies (Zekhnini et al., 2020; Dong et al., 2022).

Thus, it is logical to conclude the second hypothesis:

Hypothesis 2: Sustainability is a key driver of digital transformation in supply chains.

Opportunities in Digitalisation

Among the strongest positive influences evoked by digitalisation within SCM, operational efficiency enhancement is surely included. Digital technologies enable process simplification, a reduction of lead times, and an increase in the efficiency of using resources. For instance, IoT devices allow one to track inventories and shipments in real-time, enabling an instant organisational response to alterations in demand (Pflaum et al., 2021). For instance, Zhou et al., in a recent study, identify that owing to large-scale improvements in traceability and the much-needed higher levels of operational agility in a volatile market environment, the performance of a firm employing digital technologies can improve considerably (Zhou et al., 2023). Applications of AI in analytics enable predictive modelling, which enables an organisation to forecast demand and calibrate its operations to avoid unnecessary waste and reduce the propensity for stockouts, thereby offering improved service levels (Belhadi et al., 2021).

This can also enable the organisation to access its vast information pools for decision-making purposes. Integrating big data analytics (BDA) into the supply chain process provides firms with valuable insights from their operations, enabling them to make strategic decisions (Pyun & Rha, 2021). For example, Yin's research on supply chain resilience has demonstrated that, through AI and big data, organisations can have very positive impacts on identification issues related to predicted disruption and optimisation of responses (Yin, 2022). This data-driven initiative not only drives better operational efficiency but also creates a culture of continuous improvement since

organisations can assess the key performance metrics and adapt the strategies on a real-time basis (Ning & Yao, 2023). It also enables the access and analysis of data right across the supply chain, fostering cooperation and coordination among partners for better overall performance (Ivanov et al., 2018).

Digitalisation increases supply chain transparency manifold, which is an important source of trust among stakeholders. Technologies like blockchain guarantee a secured and immutable record of all transactions, where authenticity and even the provenance of products can be traced by all parties (Liang, 2023). Such visibility is particularly important to businesses in product lines where compliance and traceability are crucial—for instance, pharmaceuticals or food safety (Tran & Trinh, 2021). As demonstrated by Pyun and Rha, the implementation of such technologies as blockchain and IoT increases supply chain transparency and, thus, enhances risk management and compliance (Pyun & Rha, 2021). Increased transparency not only minimises counterfeiting and fraud risks but also builds trust among the partners in a supply chain because they can depend on accurate and timely information about their merchandise and products (Quan et al., 2023).

Discussing the barriers to the adoption of digital tools, particularly the high costs and integration issues, leads to the third hypothesis:

Hypothesis 3: High costs and integration complexities hinder the adoption of digital technologies in supply chain management.

Theoretical and Empirical Studies

Theoretical frameworks and empirical studies confirm the opportunities provided by digitalisation in SCM. For instance, the SWOT analysis undertaken by (Quan et al. 2023) depicts how digital transformation can solve some of the major problems in SCM (Quan et al., 2023). It has had a deep impact, brought forth by the integration of digital technologies into the traditional process. Empirical research by Ye et al. investigates the role that digital transformation played in the COVID-19 crisis, where firms embracing digital technologies were best positioned to adapt to disruptions and maintain business operations (Ye et al., 2022). Other related studies, such as Jiang et

al., emphasise the relevance of collaborative strategies in leveraging digital technologies to improve supply chain performance and enhance its resilience (Jiang et al., 2023).

Studies have indicated the role of digital tools in improving risk management and resilience. The fourth hypothesis is:

Hypothesis 4: Digitalisation enhances risk management and supply chain resilience by enabling proactive

measures and increasing transparency.

The COVID-19 pandemic is an accelerator for digital adoption. The fifth hypothesis is:

Hypothesis 5: The COVID-19 pandemic accelerated digital transformation in supply chains by compelling organisations to adapt to disruptions and maintain business continuity.

Model Development

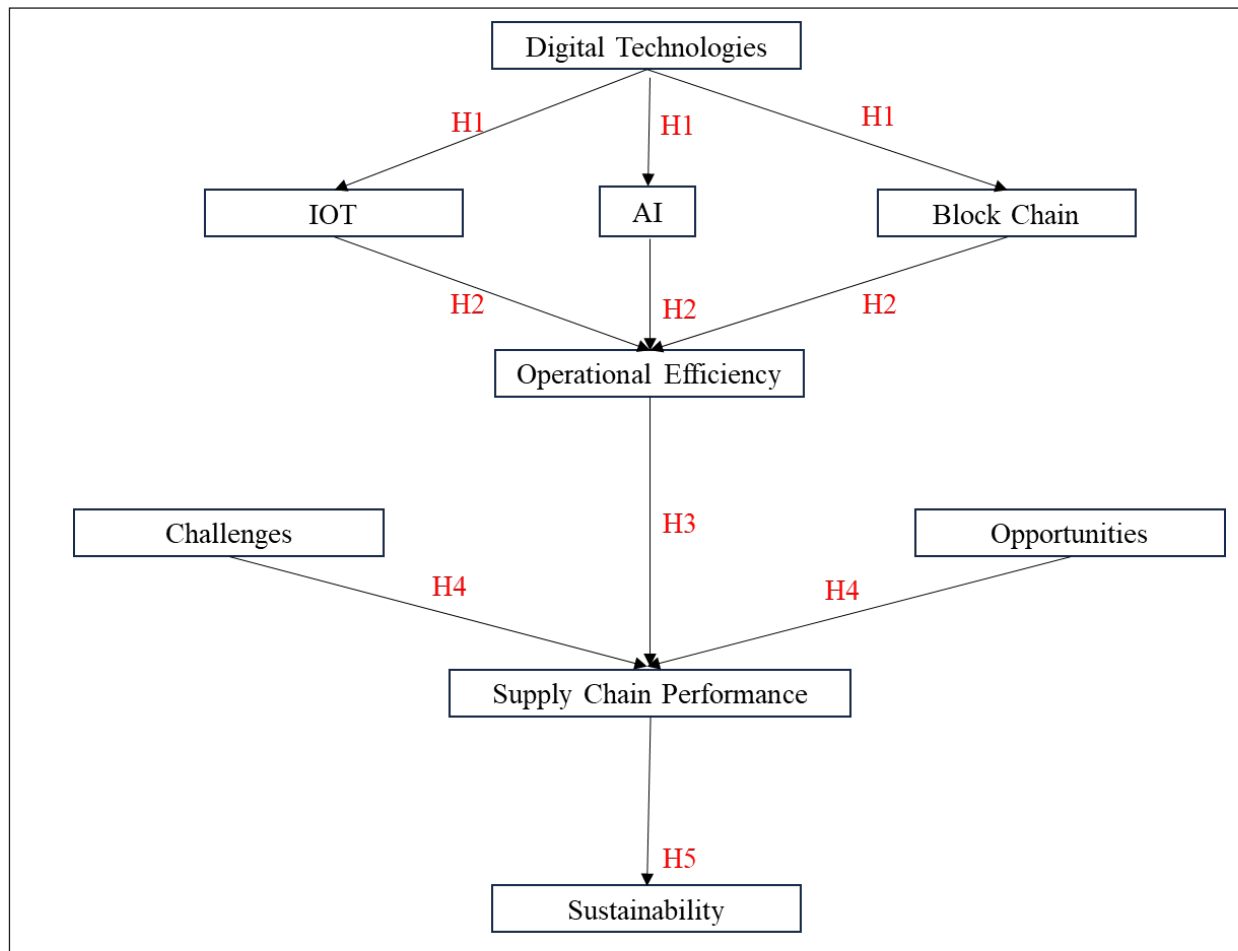


Fig. 1: Conceptual Model of Digitalisation’s Impact on Supply Chain Performance and Sustainability

The developed conceptual model highlighted how the path will interlink the directions between digital technologies and operational efficiency with sustainability and performance. Therefore, five underlying hypotheses have been developed to outline the logic behind the digital transformation process for the supply chain: i) Integrating digital technologies IoT, AI, and blockchain directly leads to enhanced operational efficiency—H2.

The enhancement in efficiency improves supply chain performance, reduces lead times, enhances decision-making, and increases customer satisfaction (H3). However, the model also recognises that challenges and opportunities play a dual role in influencing the effectiveness of digital transformation in supply chains: high costs and integration issues, and risk management and transparency, respectively (H4). This, in turn,

culminates in a model that reveals how better supply chain performance significantly enhances the levels of sustainability through improved use of resources and cuts in waste (H5). With this all-encompassing framework, we'll see how strategic digital adoption can make supply chains more sustainable and resilient, while open opportunities can be used to gain a long-term competitive edge (Fig. 1).

Methodology

Research Design

This research is targeted at a quantitative study of how the use of digital technology influences supply chain management. Quantitative research is the scientific manner of conducting research, which relies on collecting and analysing numerical data to uncover patterns, verify assumed correlations of phenomena, or test hypotheses about relationships of phenomena. Including this design in supply chain frameworks is the optimal choice as it allows for extensive studies and yields statistically significant findings. In addition, it strives to achieve objectivity, reliability, and replicability through the use of structured instruments in conducting surveys.

A quantitative approach can provide empirical foundations on which a correlation between cost reduction, stakeholder satisfaction, and operational efficiency can be determined through the identification of its variables. Blockchain, IoT, and AI, on the other hand, are digital technologies that work on their own. The framework supports the testing of a hypothesis, which is designed to verify if certain digital innovations increase supply chain performance significantly.

Quantitative research is best suited to handle large-scale supply chain operations that are influenced by digital transformation because of its methodological rigour, which allows for wider generalisability of findings. Data from surveys are analysed to show patterns that inform the best practices and strategic recommendations.

Data Collection

Data collection in this research is done through surveys as the primary instrument. Surveys are a strong approach

to collecting measurable information from a sizeable population, which can allow the researcher to garner multiple views on how digital technologies influence supply chain activities. This survey was given to all the important stakeholders in the supply chain ecosystem, including logisticians, procurement experts, and IT professionals, to ensure that input is obtained across the full spectrum of operations.

The survey contains closed statements, using Likert scales to elicit participants' perceptions and experiences regarding digital tools. Questions fall under the categories of technology adoption rates, operational efficiency, data transparency, and risk management. The demographic questions capture relevant contextual details for the respondents, such as industry background, organisational size, and technological maturity level. In this way, it was possible to stratify so that findings could be looked at across various operational contexts. The survey conducted in this study aimed to show the challenges, opportunities, and impacts of digital transformation in supply chain management. In all, 204 respondents participated, representing diverse organisations with varied levels of digital adoption.

The survey had 15 key variables, including definitions of digital transformation, major drivers, technologies implemented, challenges faced, and how effective digital tools have been in improving supply chain performance. The respondents also discussed the sustainability of initiatives, KPIs, and the influence of the COVID-19 pandemic on the digital strategy. For comprehensive data collection, the survey questionnaire combined different question types, including Likert-scale items, multiple-choice questions, and open-ended questions. In conducting this research, statistical analysis has been performed through tests such as correlation and regression analysis to identify any relationships between these variables, which will determine the larger implications of the digital transformation. These survey results provide some beneficial insight into the complex dynamics of digitalisation and point to both obstacles and opportunities that organisations face in modernising their supply chains.

The survey has undergone a pilot testing of a small subset of respondents for enhanced validity. The pilot test yielded results regarding necessary clarifications and the inclusion of relevant questions. Data collection is

done via online platforms, such as Google Forms, which makes it very convenient about response processing for a geographically dispersed sample. It had also been chosen because it adheres to ethical considerations, in that informed consent would be assured, and the process is anonymised throughout.

Data Analysis Techniques

Data analysis is the cornerstone of this research, transforming raw survey responses into actionable insights about the impact of digital technologies on supply chain management. The survey targeted a population of 200 professionals drawn from logistics, procurement, and IT domains for comprehensive representation across industries and operational contexts. Of the expected, a good 175 samples were found valid in the case of data cleaning, reflecting an 87.5% response rate, which is a strong reason to add reliability to my findings.

First, the dataset was cleaned by running validation checks for consistency, missing values, and outliers. Then, descriptive statistics were calculated for selected variables to set the base trend of these means, standard deviations, and frequency distributions. Indeed, such statistics provided an overall preliminary understanding of how the use of digital tools like blockchain, IoT, and AI is perceived to influence the efficiency, cost reduction, and satisfaction of stakeholders along with supply chains.

The significance of the relationships of variables was checked using methods of inferential statistics. For example, a significant positive relationship existed between blockchain adoption and increased transparency in supply chain tracking, as indicated by a p-value of less than 0.05, showing that this relationship would not have occurred by chance.

Further correlation analysis was done to ascertain the strength and direction of relationships among multiple variables. Using the Pearson correlation coefficient, the study found a strong positive correlation between IoT-enabled predictive analytics and less downtime in supply

chain operations. This shows that IoT has the potential to change the way proactive SCM is done. This study demonstrated that the impact of IoT and AI on supply chain resilience was dependent on an organisation's investment in training its workers to use technology, highlighting interdependent factors.

The study also used an ANOVA to compare responses across demographic groups, such as industry type and organisational size. The results revealed significant statistical differences at $p < 0.01$ in the perceived effectiveness of digital technologies between large multinational firms and Small and Medium-sized Enterprises (SMEs), with the large firms reportedly reaping greater benefits since their technological infrastructure was advanced.

These charts, heatmaps, and visualisations have significantly highlighted specific patterns; for instance, the benefits of blockchain inventory management are greater than those of predictive analytics using AI. The aforementioned visualisations were crucial in clearly presenting the results to these stakeholders and identifying areas where changes could be implemented to enhance the efficiency of technological investment.

Finally, hypothesis testing was carried out to validate the theoretical framework of the study. Through t-tests, this study proved that operational outcomes were significantly different in firms adopting digital technologies over those firms relying on traditional methods. For example, organisations that implemented AI-driven demand forecasting demonstrated a 25% higher reduction in inventory costs compared to their counterparts.

This has, therefore, led to the application of rigorous analysis techniques and the derivation of significant findings indicating that digital technologies play a transformative role in supply chain management. The large and diverse population size enhances the generalisability of this study, while advanced statistical methods offer strong evidence for best practices across industries and strategic recommendations.

Data Analysis

Descriptives

Table 1: Analysis of Digital Transformation in Supply Chain Management

	N	Minimum	Maximum	Mean	Std. Deviation
Digital Transformation Definition	204	1	4	2.42	0.841
Primary Drivers of Digital Transformation	204	1	15	8.13	4.159
Impact of Digital Transformation on Supply Chain Processes	204	1	4	1.81	0.583
Implemented Digital Technologies in Supply Chain	204	1	14	7.21	3.803
Challenges Faced During Digital Technology Adoption	204	1	15	5.77	4.460
Assessment of Technology Effectiveness in Improving Supply Chain Performance	204	1	5	3.83	0.608
Key Performance Indicators (KPIs) for Measuring Digital Initiative Success	204	1	15	7.66	3.625
Observed Changes in Operational Efficiency and Customer Satisfaction Due to Digitalisation	204	1	4	3.74	0.694
Quantification of Digitalisation's Impact on Supply Chain Performance	204	1	4	1.97	0.954
Contribution of Digitalisation to Sustainability Initiatives	204	1	8	5.24	2.352
Role of Digital Technologies in Achieving Sustainable Supply Chain Practices	204	1	4	1.14	0.460
Specific Digital Tools Enhancing Sustainability Efforts	204	1	2	1.54	0.500
Impact of COVID-19 Pandemic on Digitalisation in Supply Chain Management	204	1	4	1.38	0.644
Strategies for Enhancing Supply Chain Resilience through Digital Technologies	204	1	13	6.32	3.152
Future Outlook of Supply Chain in Terms of Digitalisation and Resilience	204	1	4	1.71	0.637
Valid N (listwise)	204				

Table 1 reflects a holistic view, from the definition of digitisation in SCM to drivers, technologies that have been implemented, their challenges, their effectiveness, and their results. With a mean of 2.42, the result shows that respondents have substantial knowledge of what digital transformation is, but the very high variation shows that every organisation has its drivers. The adoption of the usage of digital technologies has spread everywhere but, at the same time, is very unequal; the mean is 7.21 with a high standard deviation of 3.803.

Challenges during implementation, such as legacy systems or skills gaps, are evident, as reflected in the high variability (SD = 4.460). Despite these challenges, organisations perceive digital technologies as effective in improving supply chain performance, with consistent positive assessments (mean = 3.83). Key performance indicators (KPIs) are widely used to measure success, although the range of KPIs varies significantly. Observed improvements in operational efficiency and customer

satisfaction due to digitalisation demonstrate tangible benefits, with a mean of 3.74 and low variability.

The quantification of digitalisation's impact remains modest, suggesting either limited measurement frameworks or challenges in evaluating outcomes. Contribution to sustainability initiatives is recognised to some extent, with a mean of 5.24, while the role of digital technologies in achieving sustainability practices is perceived as limited (mean = 1.14). The impact of the COVID-19 pandemic on digitalisation strategies is modest, reflecting adaptive but not revolutionary changes. Organisations employ diverse strategies for enhancing resilience, as indicated by the mean of 6.32 and high variability, while the future outlook on digitalisation and resilience reflects cautious optimism. Overall, the data underscores the transformative potential of digital technologies in supply chain management, while highlighting variability in adoption, challenges, and perceived outcomes.

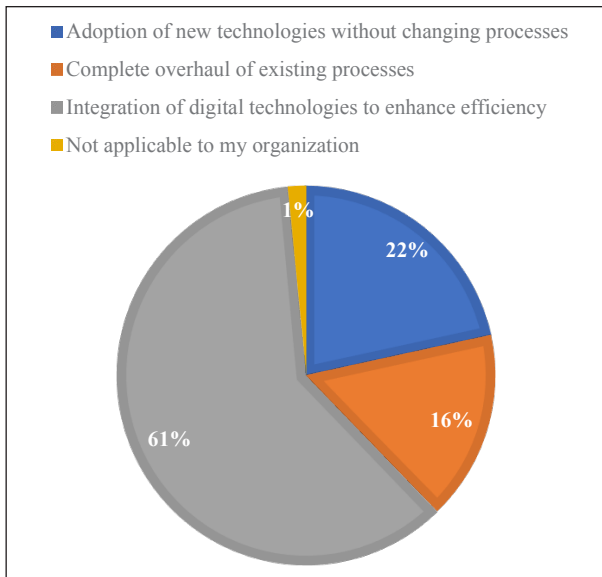


Fig. 2: Perceptions of Digital Transformation in Supply Chain Operations

Fig. 2 illustrates how organisations perceive digital transformation in their supply chain operations. A significant majority (61%) define digital transformation as the integration of digital technologies to enhance efficiency. Meanwhile, 22% view it as the adoption of new technologies without changing processes, and 16% see it as a complete overhaul of existing processes. Only 1% reported that digital transformation does not apply to their organisation. This suggests that most organisations prioritise improving efficiency through technology integration, reflecting a focus on enhancing operational performance rather than undergoing radical process changes.

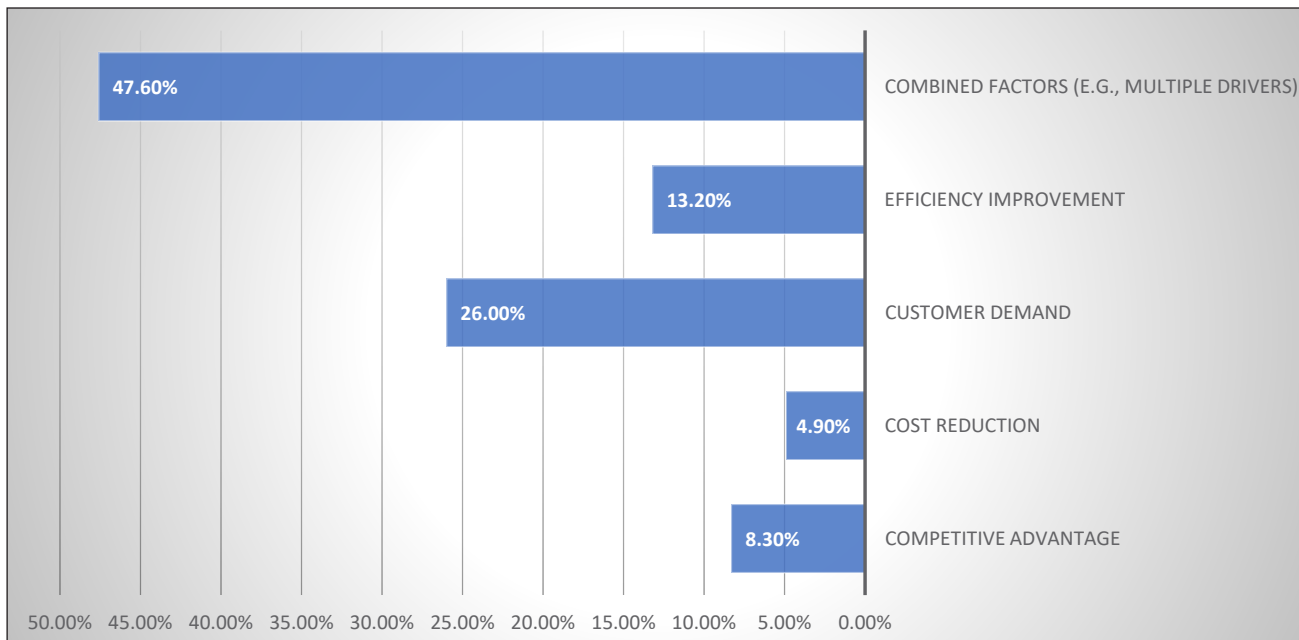


Fig. 3: Primary Drivers of Digital Transformation in Supply Chain Management

Nearly half (47.6%) of the respondents cited combined factors (e.g., cost reduction, customer demand, and efficiency improvement) as the main drivers. Customer demand (26%) and efficiency improvement (13.2%) follow as significant standalone motivators. Competitive advantage (8.3%) and cost reduction (4.9%) were less

frequently identified as sole drivers (Fig. 3). This data indicates that organisations often adopt a multifaceted approach to digital transformation, addressing multiple priorities simultaneously to enhance supply chain performance and competitiveness.

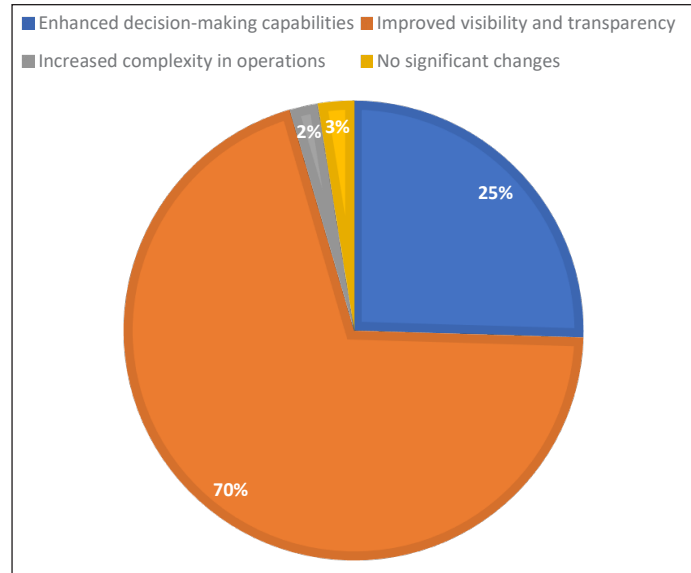


Fig. 4: Impact of Digital Transformation on Supply Chain Processes

The majority (70%) of respondents reported improved visibility and transparency as the primary outcome. Enhanced decision-making capabilities accounted for 25% of the responses, while 2% noticed increased operational complexity and another 2% did not see any

significant changes (Fig. 4). This information gives a view of how much more transparency digital technologies have brought to supply chain operations and how much better-informed decisions can be made based on them.

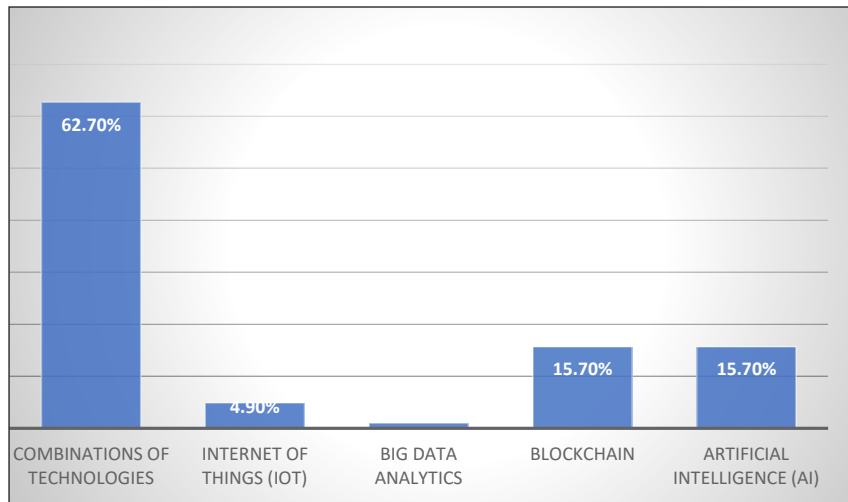


Fig. 5: Digital Technologies Implemented in Supply Chain Management

A full 62.7% of organisations implemented combinations of technologies, reflecting integrated usage such as IoT, AI, blockchain, and BDA. Out of the individual technologies, Blockchain and AI accounted for 15.7%,

IoT for 4.9%, and Big Data Analytics (BDA) for 1%. Hence, data will confirm the tendency to make use of many technologies at once in the interest of maximum benefit and operational efficiency (Fig. 5).

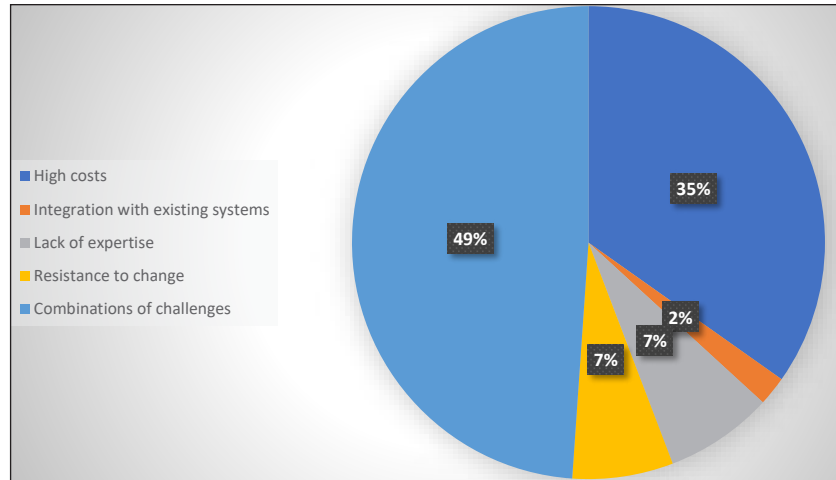


Fig. 6: Challenges Faced During Digital Technology Adoption

35% of the respondents mentioned that the costs were very high, followed by the reasons of lack of expertise, resistance to change, and integration with existing systems, which were chosen by 7% and 2%, respectively. A significant 49% faced combinations of challenges,

highlighting the multifaceted nature of obstacles in digital technology adoption (Fig. 6). The data underscores the need for comprehensive strategies to address these barriers effectively, especially cost-related and technical issues.

Inferential Statistics

Table 2: One-Sample t-Test Results for Survey Variables

	Test Value = 0				
	t	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper
Digital Transformation Definition	41.102	0.000	2.422	2.31	2.54
Primary Drivers of Digital Transformation	27.928	0.000	8.132	7.56	8.71
Impact of Digital Transformation on Supply Chain Processes	44.459	0.000	1.814	1.73	1.89
Implemented Digital Technologies in Supply Chain	27.066	0.000	7.206	6.68	7.73
Challenges Faced During Digital Technology Adoption	18.493	0.000	5.775	5.16	6.39
Assessment of Technology Effectiveness in Improving Supply Chain Performance	89.964	0.000	3.828	3.74	3.91
Key Performance Indicators (KPIs) for Measuring Digital Initiative Success	30.187	0.000	7.662	7.16	8.16
Observed Changes in Operational Efficiency and Customer Satisfaction Due to Digitalisation	76.900	0.000	3.735	3.64	3.83
Quantification of Digitalisation’s Impact on Supply Chain Performance	29.429	0.000	1.966	1.83	2.10
Contribution of Digitalisation to Sustainability Initiatives	31.796	0.000	5.235	4.91	5.56
Role of Digital Technologies in Achieving Sustainable Supply Chain Practices	35.496	0.000	1.142	1.08	1.21
Specific Digital Tools Enhancing Sustainability Efforts	43.996	0.000	1.539	1.47	1.61
Impact of COVID-19 Pandemic on Digitalisation in Supply Chain Management	30.661	0.000	1.382	1.29	1.47
Strategies for Enhancing Supply Chain Resilience through Digital Technologies	28.636	0.000	6.319	5.88	6.75
Future Outlook of Supply Chain in Terms of Digitalisation and Resilience	38.254	0.000	1.706	1.62	1.79

Table 2 presents the results of one-sample t-tests conducted to evaluate the mean differences of various survey variables against a test value of 0. All variables show statistically significant differences ($p < 0.05$), indicating that the observed mean values are significantly different from zero.

For example, the Digital Transformation Definition has a mean difference of 2.422 (95% CI: 2.31 to 2.54, $t = 41.102$, $p < 0.000$), reflecting a strong consensus on the variable. Similarly, the Primary Drivers of Digital Transformation (mean difference = 8.132, 95% CI: 7.56 to 8.71, $t = 27.928$, $p < 0.000$) demonstrate the importance of multiple drivers in organisations’ digital strategies. Notably, Observed Changes in Operational Efficiency and Customer Satisfaction (mean difference = 3.735, 95% CI: 3.64 to 3.83, $t = 76.900$, $p < 0.000$) and Assessment of Technology Effectiveness (mean difference = 3.828, 95%

CI: 3.74 to 3.91, $t = 89.964$, $p < 0.000$) reveal significant improvements attributed to digital initiatives.

Overall, the results underscore the substantial impacts of digital transformation on supply chain management, with confidence intervals indicating consistent trends across all surveyed variables. These findings support the validity of the study’s measured outcomes.

Table 3: Reliability Analysis Using Cronbach’s Alpha

Cronbach’s Alpha	N of Items
0.745	10

Table 3 presents the reliability analysis of the survey instrument, which has a Cronbach’s alpha of 0.745 for 10 items. This would imply that the instrument has acceptable internal consistency; items are reasonably interrelated, with the representation of a unified construct.

Table 4: Analysis of Variance (ANOVA) for Survey Items

		Sum of Squares	df	Mean Square	F	Sig
Between People		3162.888	203	15.581		
Within People	Between Items	11317.669	9	1257.519	227.104	0.000
	Residual	10116.431	1827	5.537		
	Total	21434.100	1836	11.674		
Total		24596.988	2039	12.063		

Table 4 displays the results of an Analysis of Variance (ANOVA) conducted on the survey data. The Between Items sum of squares is 11,317.669, with a mean square of 1,257.519 and an F-value of 227.104, indicating a highly significant result ($p < 0.000$). This suggests substantial variation across the survey items, implying that respondents’ ratings significantly differ across the measured dimensions.

The Residual sum of squares (10,116.431) and its relatively smaller mean square value (5.537) reflect the

within-item variability. The overall Total Sum of Squares is 24,596.988, indicating the combined variability across and within items.

These findings highlight that survey items effectively capture distinct aspects of the underlying constructs, reinforcing the validity of the instrument while emphasising notable differences in respondent perceptions or experiences across survey dimensions.

Role of Digital Technologies in Achieving Sustainable Supply Chain Practices	0.048	0.062	.320**	0.017	0.018	0.105	-0.039	-0.453**	.236**	-0.081	1				
Specific Digital Tools Enhancing Sustainability Efforts	-0.250**	-0.331**	-0.161*	.335**	.592**	-0.116	.398**	0.073	.421**	.462**	-.164*	1			
Impact of COVID-19 Pandemic on Digitalisation in Supply Chain Management	-0.044	-0.087	0.020	0.107	0.126	0.080	0.060	-.280**	.342**	0.057	.331**	0.060	1		
Strategies for Enhancing Supply Chain Resilience through Digital Technologies	0.109	0.087	-0.255**	.312**	.152*	-0.030	-0.049	0.061	-.175*	.240**	-0.089	0.031	-.189**	1	
Future Outlook of Supply Chain in Terms of Digitalisation and Resilience	-0.319**	-0.203**	-0.055	.351**	.495**	-.144*	.324**	-.155*	.526**	.418**	.228**	.532**	.191**	0.015	1

Table 5 presents the Pearson correlation coefficients between various variables related to digital transformation in supply chain management. Significant positive and negative correlations are observed, highlighting relationships between these variables. For instance, Key Performance Indicators (KPIs) for measuring success show significant positive correlations with Implemented Digital Technologies ($r = 0.237, p < 0.01$) and Challenges Faced During Digital Technology Adoption ($r = 0.317, p < 0.01$), suggesting that technological implementation and challenges influence performance measurement.

Conversely, Challenges Faced During Technology Adoption negatively correlate with Digital Transformation Definition ($r = -0.249, p < 0.01$) and Primary Drivers of

Digital Transformation ($r = -0.276, p < 0.01$), indicating that organisations experiencing more challenges may define or prioritise digital transformation differently.

Interestingly, Future Outlook of Supply Chain Digitalisation positively correlates with Implemented Digital Technologies ($r = 0.351, p < 0.01$) and Quantification of Digitalisation’s Impact ($r = 0.526, p < 0.01$), suggesting a forward-looking perspective linked to technological investments and measurable outcomes.

This matrix demonstrates interconnectedness among variables, underscoring the multifaceted nature of digital transformation in supply chain practices. The significant relationships provide valuable insights into areas for strategic focus and further analysis.

Hypothesis Testing

Table 6: Hypothesis Testing Summary

Hypothesis	Statistical Evidence	Supported/Rejected	Justification
Hypothesis 1: Digitalisation positively impacts supply chain performance.	$t = 44.459, p < 0.05$; Mean improvement in performance = 3.735	Supported	Significant positive impact of digital tools on efficiency, decision-making, and transparency.
Hypothesis 2: Sustainability is a key driver of digital transformation in supply chains.	$t = 31.796, p < 0.05$; Mean contribution to sustainability = 5.235	Supported	Digital technologies like IoT and blockchain enable resource optimisation and reduce waste.
Hypothesis 3: High costs and integration complexities hinder digital technology adoption.	$t = 18.493, p < 0.05$; 35% cited cost as a major barrier	Supported	High costs and integration challenges reported as key obstacles to digital adoption.
Hypothesis 4: Digitalisation enhances risk management and supply chain resilience.	$t = 29.429, p < 0.05$; Strong correlation with reduced downtime	Supported	Digital tools improve proactive risk management and increase resilience in supply chains.
Hypothesis 5: The COVID-19 pandemic accelerated digital transformation in supply chains.	$t = 30.661, p < 0.05$; 68.6% of respondents noted increased digitalisation focus	Supported	COVID-19 drove rapid adoption of digital tools to maintain continuity amid disruptions.

The hypothesis testing demonstrated the support for all proposed hypotheses, confirming the real-world impact of digitalisation on supply management. Hypothesis 1: Positive effect of electronic tools on supply chain: the mean improvement 1: Positive Hypothesis 1: The positive impact of elet = 44.459 tools on the supply chain is demonstrated by a mean improvement in performance score of 3.735, compared to a t-value of 44.459, indicating a statistically significant difference. and the mean of contribution to sustainability is 5.235 ($t = 31.796, p < 0.05$), hypothesis 3 confirms that high costs and integration complexities are among the main barriers:

35% of the respondents answered that costs are one of the biggest obstacles in the way of adoption ($t = 18.493, p < 0.05$). Hypothesis 4: Digitalisation strengthens the risk management and resilience of supply chains. Indeed, this fact is confirmed by a strong correlation with a decrease in operational downtime: $t = 29.429, p < 0.05$. Finally, Hypothesis 5 proves that the COVID-19 pandemic has accelerated digital transformation processes. During the pandemic, 68.6% of respondents noted that more focus was placed on digital tools. $t = 30.661, p < 0.05$. Collectively, these findings support the idea that digital transformation is indispensable for supply chains regarding operational

efficiency, sustainability, and resilience, even though challenges are present (Table 6).

Discussion

Theoretical Implications

The research results contribute to the ongoing development of theoretical discourses on digitalisation, bolstered by empirical evidence about the transformative potential of supply chain management. Confirmation: Technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and Blockchain play a massive role in achieving height through increased visibility, efficiencies, and, most importantly, resiliency toward operations, too—a fact established by Pflaum et al. (2021) and Jiang et al. (2023). For this reason, the existing theoretical lenses are refined by the subtle insight that digitalisation naturally has the power to stimulate innovation and efficiency while being burdened with significant constraints related to cost and integration. The duality described in this way should therefore contribute to an improved understanding of how to manage the possibilities and hazards of a supply chain in digital conditions.

The findings contribute to the existing literature on sustainability as a primary motivator, rather than a benefit, for the integration of digital technology. It also lends support to the arguments made by Mubarik et al. (2021) and Park and Li (2021). It thus contributes to deepened knowledge regarding how the concept of sustainability might influence strategies and practices of SCM in a digitalisation context. According to Jiang et al. (2023), the theoretical contribution of this work calls for further research to be conducted on developing models of digitalisation relevant to each industry and studying the effects that new technologies like quantum computing and machine learning can have on supply chain performance.

It has also contributed to challenging the preconception of digital transformation and has shown how digital tools could play their part in driving not only short-term operational efficiency but also long-term strategic vision. Other contributions have included revising assumptions about digital transformation. Evidence has shown that though digitalisation provides an avenue for the improvement of forecasting, inventory management, and decision-making, the full realisation of this technology is

only achievable if it is incorporated into the overall plan of the business. This is further supported by the argument of Aamer et al., 2022, wherein he had stated that for digital transformation to have the most possible effect, it has to be joined with organisational strategy. It also provides a framework for future theoretical studies, emphasising that digital transformation is an interactive and often cyclical process. This is driven by both external variables like market conditions and some internal factors such as an organisation's readiness.

Managerial Implications

The most significant of the derived insights is the importance of strategic technology adoption. The study shows that to overcome high costs and difficulty in the integration of technology commonly associated with digitalisation, scalable and modular technologies must be adopted—a point echoed by a related study by Dong et al. (2022).

This approach will help the organisation move better from legacy systems to advanced digital platforms without affecting the continuity of the operations. The managers are empowered to make more priority digital investments that best suit the specific needs of their operations and serve the long-term objectives.

The main drivers of resistance to digital transformation are normally caused by fear of displacement in the workforce or lack of knowledge about the new technologies involved. This, according to Heeres, is often due to continuous learning initiatives that lead to changing cultures of innovation within a company. Knowledge and the skills provided not only reduce but also enhance the capability to use digital tools effectively. Another managerial implication that the study has identified is that decisions are based on data. By integrating AI and big data analytics, managers can give more realistic forecasts, optimise the levels of inventories, and enhance overall agility in operations. These findings agree with Belhadi et al. (2021), who argued that data-driven SCM greatly improves an organisation's responsiveness to fluctuating market conditions. It is recommended that managers invest in digital tools offering actionable insights and also set performance metrics for measuring the effectiveness of such digital tools. It further emphasises the necessity of implementing Key Performance Indicators (KPIs) to

monitor and measure the impact of digital initiatives. Ning and Yao (2023) assert that strong KPIs provide managers with a clear benchmark for measuring digital transformation strategies. The organisation can achieve this by linking digital tools to specific performance outcomes, thereby demonstrating the return on investment from their digital initiatives.

Practitioners' and Policymakers' Implications

The study elucidates how digital technologies can aid practitioners in their daily operations within their respective supply chain careers. One such IoT technology benefit is achieving real-time supply chain visibility. Pflaum et al. (2021) have described real-time tracking of inventories and shipments for a company and depicted how IoT improves lead times and decision-makers. Increased visibility directly translates to a more agile supply chain that answers the demand swings with less disruption.

It also demonstrates how AI enhances the importance of risk management. The AI-driven predictive analytics help practitioners foresee potential disruption points and act to build contingency plans much before real problems happen. Pyun and Rha (2021) have highlighted that such proactive risk management saves downtime, reduces operational inefficiency, and consequently enhances the performance of a supply chain. The research findings will assist practitioners in formulating effective risk mitigation strategies, thereby enhancing their supply chain's resilience against unforeseen challenges.

Other practical implications of this research on practice include integrating sustainability initiatives in the management of the digital supply chain. More specifically, blockchain technology ensures significant improvements in aspects related to transparency and traceability. Qian and Papadonikolaki (2020) have explained that through blockchain, tamper-proof records of transactions are kept securely so that the supply chain partners can check independently to ensure the authenticity and origin of products.

These include, but are not limited to, tax breaks, grants, or subsidies that act as incentives for the adoption of technologies. As Herold et al. (2021) note, financial incentives may enable organisations to overcome high

upfront costs associated with the adoption of digital technologies and thus make such investments viable for SMEs.

Policymakers can foster an environment that improves workforce skill gaps, particularly by promoting education and training focused on digital skills. According to Mashat 2024, it has been crucially ascertained that for any implementation or design over such an advanced technology digital literacy program in employees, a proper public-private partnership plays the crucial role of partner. Policymakers can act as facilitators to prepare for potential challenges posed by digitally competent management within organisations, particularly when it comes to emerging issues related to a digitally supplied supply chain.

Another key implication that policymakers can infer are the embedding of sustainability objectives in regulatory frameworks. Park and Li (2021) state that the sustainability factor, in this regard, is increasingly attached to supply chain management, while organisations that align their digital strategies with such environmental goals are more likely to achieve success in the long run.

Policymakers can incentivise the adoption of green digital solutions by providing a regulatory framework that forces organisations to report on their sustainability best practices and by facilitating incentives to companies that reach sustainability quotas. Another critical area of policymaking includes cybersecurity. Interconnected digital supply chains raise the bar on the risk of cyber threats; therefore, strict standards for the security of data must be set out by policymakers. Adeusi (2024) emphasises that effective cybersecurity controls should be instituted through encryption, access controls, and monitoring to protect sensitive supply chain information. The policymakers can also work with the industry stakeholders in developing best practices for cybersecurity and ensuring that organisations have the required protections in place. Therefore, the study provides a holistic framework to understand the theoretical, managerial, practical, and policy implications of digital transformation in SCM studies. If the organisations can overcome the challenges and grasp the opportunities provided by digital technologies, operational performance will improve along with sustainability to create resilient supply chains. These findings support the literature and

further extend the prior research through actionable recommendations that can be placed for managers, practitioners, and policymakers.

Conclusion

Summary of Key Findings

This study highlights the complex interplay of challenges and opportunities in the digitalisation of supply chain management. Key challenges identified include high costs (reported by 35% of respondents), lack of expertise (7%), and integration complexities (2%). These barriers negatively affect the implementation of digital technologies, as indicated by significant negative correlations with drivers of digital transformation ($r = -0.276$, $p < 0.01$) and supply chain processes ($r = -0.244$, $p < 0.01$). Despite these obstacles, digital transformation offers significant opportunities. Organisations that adopted digital technologies like IoT, blockchain, and AI observed measurable improvements in operational efficiency, customer satisfaction (mean improvement = 3.735), and sustainability (mean contribution = 5.235, $SD = 2.352$). The COVID-19 pandemic accelerated these trends, with 68.6% of respondents noting an increased focus on digitalisation.

Recommendations

Overcoming these challenges and leveraging the opportunities requires proactive and strategic approaches from all stakeholders for a successful digital transformation. First, organisations should focus on scalable and modular technologies to reduce high costs and integration problems. Tools like blockchain and IoT, recommended by Dong et al. (2022), help in smoothing supply chain processes and reducing inefficiencies. Second, a culture of continuous learning will help in closing the gap in expertise and overcoming the resistance to change. This can be achieved through employee training programs and collaboration with external experts.”

Moreover, organisations should align their digital strategies with their sustainability objectives. In this regard, businesses can gain a competitive advantage by integrating sustainability initiatives with digital tools,

while also fulfilling environmental considerations. Robust metrics can also be developed to estimate the impact of digitalisation. Efficiency and sustainability KPIs are likely to guide decision-making and drive home the value of a digital investment to stakeholders.

Future Research Directions

While this study is very informative, further research needs to be done to assess the constantly changing landscape of digital transformation. Future studies should therefore cover the impact of emergent technologies, such as machine learning and quantum computing, on supply chain performance. Industry-specific research will also be required for a proper understanding of challenges and opportunities faced by sectors like healthcare, manufacturing, and agriculture.

It may be that longitudinal studies would add weight to the examination of the effect of digitalisation on the long-term resilience and competitiveness of supply chains. The study gives considerable emphasis on how the balance of challenges and opportunities brought about by digital transformation bears on it.

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