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The role of artificial intelligence on digital supply chain in industrial companies mediating effect of operational efficiency

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A B S T R A C T

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The research aims to investigate the potential impact of Artificial Intelligence (AI) on the digital supply chain in light of extant literature on the Decision-Oriented Information (DOI) theory and the Technology-Oriented Enterprise (TOE) framework. The research further attempts to unpack the strategic implications of AI integration in supply chain management, and its association with operational excellence and business model innovation. The study is exploratory and employs a mixed-methods approach. We develop propositions that examine the decision-making processes within AI-enhanced supply chains based on an analysis of concepts central to the DOI theory. We also employ the TOE framework to develop further propositions regarding the technological infrastructure required for AI implementation. Empirical case studies encompassing AI applications in different industries (e.g. manufacturing, healthcare, and pharmaceuticals) are presented to gain a broad perspective of the impact of AI on the digital supply chain. AI technologies inherently make supply chains more agile, transparent, and responsive. Machine Learning algorithms allow for more accurate forecasting and demand management under conditions of supply chain risk and volatility. Robotics and automation, allow for greater flexibility and efficiency in executing operations and logistics. Additionally, the successful implementation of AI is heavily contingent on the organization's current level of technological infrastructure and its alignment with its current and future business objectives. Furthermore, the DOI theory and TOE framework may serve as a blueprint for how one could evaluate AI implementation beyond the scope of supply chain management.

1. Introduction

Operational efficiency is a determining factor of success or failure for companies that are able to drive towards providing high-quality service with short response times while cutting costs (Cai et al., 2019), Operational efficiency is achieved by working through the effective and strategic use of people, technology, time, and resources to ensure that procedures are carried out in the most cost-effective and productive manner, while causing the least waste. by implementing dynamic document generation to allow businesses to keep up with standards, operational efficiency in today's corporate environment is about much more than cost cutting. Moreover, The first section of this paper investigates how businesses measure operational efficiency, what drives them to become operationally efficient, and how enhancements in efficiency reshape strategy and decision-making (Bell et al., 2018) The latter half of this Research Paper investigates the various hurdles faced by firms seeking to become and remain operationally efficient, as well as revealing the tactics businesses are using to surmount them. Operational efficiency is made up of several different value-add and value-light elements that make up a digital supply chain between security, scalability, and standardization. Scalability is one of the well-known tenets of (AI), with (AI) solutions that have the ability to grow along with a company's ever-increasing variety of operations, whether that's in terms of volume,

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complexity, or geographic area. Security is another essential piece, with (AI) systems coming with robust security measures that batten down sensitive data and keep the cyber wolves at bay, enabling a secure supply chain (Katsaliaki et al., 2022). Furthermore, The final piece of the puzzle is standardization. With the use of established protocols and formats for the seamless exchange of data and syncing of processes among an array of systems and stakeholders, businesses can move with greater certainty, reliability, and consistency into whatever future it is in which it is possible (AI) will be the new standard way of managing the complexity of entire supply chains (Iris & Lam, 2019) This paper provides an understanding of the role operational efficiency plays in various aspects of a business's performance, using the latest empirical and theoretical insights to provide a focused view of its importance. Based on the latest empirical research, the paper begins by showing how businesses measure operational efficiency and what drives them toward efficiency. The paper then uncovers how efficiency enhancements alter a business's strategy and decision-making (Sharabati et al., 2023).

However, The second half of the Research Paper shows the various hurdles businesses must navigate on their way to becoming and staying highly operationally efficient, and it provides a look at the tactics businesses are using to achieve that state. One area where recent years have seen a tremendous amount of change is the digital supply chain. The growth of online shopping has led to ever-more sophisticated logistics systems that are less one-size-fits-all and more flexible and dependable. One innovation to come out of this has been smart procurement. Smart procurement is the automation, streamlining, and improvement in accuracy of essential procurement operations using artificial intelligence (AI), machine learning, and other smart technologies that create value (Elijah et al., 2018) Today's article breaks down the role of smart procurement is playing in the transformation of the digital supply chain and how the relationship between the two is critically important to creating value. Our aim in this paper is to demonstrate the convergence of the Decision-Oriented Information (DOI) theory and Technology-Operations-Economics (TOE) framework, in order to create a unified and flexible base for the analysis of how artificial intelligence (AI) is transforming and improving decision-making, productivity, and the competitive stance a firm is able to take in today's rapidly-evolving market (Wang et al., 2019) Doing so would allow academics and practitioners to evaluate the creative applications of (AI) as the "digital brain" of the digital supply chain; and examines how (AI) allows a firm to go from the optimization of operations all the way up to the excitation of firm growth (Olan et al., 2021). We believe that the synergy shown by DOI theory and TOE framework enables us to paint a more complete picture of the underlying dynamics of the digital supply chain than the two lineages would be able to do individually, and at the same time underscores the strategic importance of (AI) for the achievement of operational excellence (Venkatesh & Bala, 2008)We hope that the unveiling of these futurological insights on the tomorrow of supply chain management, and the strategic implications of new technology for supply chain logistics, will enable scholars and the leaders in this slice of management that read them to better understand how whatever the supply chain is, these new information systems coming up over the next few years will warp and distort it, and the way the broad of competitive activity across firms in this management area is likely to evolve (Nandi et al., 2020)

Many corporations use AI for increased efficiency in their supply chains and logistical networks, but these efforts generally fail: According to Capgemini Research Institute's Marketing AI in the Digital Supply Chain, Managers who understand operational efficiency and its optimization will find that AI can be introduced to the supply chain. A firm could use the AI blueprint we unearthed here to understand AI adoption, workforce training, and change management in digitization This research aims to elucidate the influence chain of AI adoption in supply chain management to establish theoretical constructs that can facilitate a comprehensive appreciation of the implications of embedding AI in digital supply chains (Ali et al., 2023; Hatamlah, Allan, et al., 2023). Specifically, this research is conducted to address the following questions:

RQ 1: Is there a relationship between Artificial Intelligence and the digital supply chain?

RQ 2: Does Operational Efficiency influence the relationship between Artificial Intelligence and the digital supply chain?

2. Literature Review

2.1 Artificial Intelligence

Numerous businesses have pursued digital integration in their processes over the last two decades. "Industry 4.0" as we hear it uttered in the circles of business of late (Alazab, 2024). The technology responsible for this is Artificial Intelligence (AI), allowing devices to communicate among themselves and with machines (Ali et al., 2023; Bell et al., 2018). An essential technology for AI is a large set of data (Nandi et al., 2020). This success of AI in adapting and executing complex tasks with speed and accuracy with large amounts of data is an asset to supply chain operations (Toorajipour et al., 2021). Although the concept of AI is not new (Olan et al., 2021), the wide-ranging applications of AI technology in managing the supply chain are only coming into view now, e.g., AI enables the supply chain to make intelligent and adaptive decisions and predict and resolve problems in the forward (Kim & Shin, 2019). This active AI system is used to optimize delivery, sending orders to warehouses and goods to workers to minimize the time it takes to appear on the delivery dock to a waiting truck (Toorajipour et al., 2021). The network of value chains must have their processes "work" with each other and with the vendor which can be facilitated by automating the processes used to ensure the required compliance requirements are met. With reduced spending and improved "interoperability," the network of value chains runs smoothly (Kim & Shin, 2019). This limited stack of inventory will improve the firm's ability to predict demand in the commercial industry which changes often and quickly today. AI's contribution to consumer engagement from a retail perspective is significant with an ROI that can average three years and provide up to a 10% reduction in expenditure (Hatamlah, Allan, et al., 2023; Venkatesh & Bala, 2008): A.I. powered bots will do more than answer consumers frequently asked questions (FAQs): Once trained, they will be able to interact individually with consumers as the recognize patterns, for consumers who have questions in more than one area at the same time as well as to help potential buyers to ask questions regarding which article of clothing is appropriate for a specific situation (Salhab et al., 2023). The matter of (AI) is broached with a focus on the transformative power that technology brings to bear on the digital supply chain, and the fusion of artificial intelligence with other advanced technologies to automate and enhance supply chain processes. Business Professor Genevieve Bell is quick to point out that (AI) is about far more than just adopting the latest technology. "It's about fundamentally changing business operations and the way businesses operate. And the reason why this approach to the supply chain becomes so important is that we are dealing with such small margins and such large scale. Any way to be more efficient, any way to get rid of old inefficiencies is a win," Bell told Intel. Re-imagining the supply chain in the context of the digital economy is clearly easier said than done, but Intel explained that (AI) technologies are interesting in that they provide the elasticity that will allow innovations to scale up or down as required, "so that businesses can handle peak loads, introduce new products or enter new markets."

Scalability is one of the foundational design principles of the technologies that underpin (AI). Modular architectures enable systems to add or discard components as demand changes, while cloud-based infrastructure ensures solutions can scale up when demand spikes and scale down during quiet times, keeping resource utilization optimized and costs under control (Nurgazina et al., 2021). For many organizations, scalability is considered a non-negotiable as they look to navigate the digital age. Scalable organizations grow and evolve, and the design principle asserts that supply chain operations must evolve alongside. As they increase the volume of goods they produce and deliver, diversify their product lines, and enter new geographic markets, organizations and the (AI) systems that underpin their supply chains must be scalable by design, capable of handling a wide variety of workloads and adaptable to changing business landscapes (Nasir et al., 2022). Geographical expansion is the second aspect of scalability that the theoretical framework deems to be crucial. As scalable organizations globalize, the design principle insists, that their supply chain (AI) systems must support international trade, regional regulations, and cross-border logistics; i.e., they should be capable of plugging into regional payment gateways and customs systems, as well as deploying industry-leading language translation services to ensure true global coverage (Thakur & Breslin, 2020).

Security is one of the central tenets of the autonomous supply chain, recognizing the need to protect digital assets and garner trust in a system that acknowledges that as AI advances (Solfa, 2022). Autonomous supply chain systems are developing with robust security architectures that incorporate advanced cryptographic techniques, multi-factor authentication, and continuous monitoring to keep data breaches and unauthorized access at bay (Sobb et al., 2020). This security focus is vital for ensuring that the supply chain's integrity is maintained and its reliability engenders consumer trust (Etemadi et al., 2021).

Standardization: Theoretical frameworks for (AI) also underscore the need for standardization (Kovács & Falagara Sigala, 2021). Standardization is vital in terms of promoting uniformity in business processes and the availability of standards and open APIs to enable systems to integrate seamlessly with one another and interoperate will help to reduce the complexity associated with managing myriad systems while making it easier for companies to exchange data and ensure processes are synchronized (Nurgazina et al., 2021). Here, the way AI automates certain tasks suggests that organizations can start to better and more consistently utilize real-time data to ensure that levels of data freshness are maintained to ensure that such variables as perishable goods for example, are properly governed for operational cohesion and consistency in a more general sense, which are two of the more vital elements when it comes to preserving operational efficiency and customer satisfaction in the digital supply chain (Andiyappillai, 2019).

2.2 Digital Supply Chain

The digital supply chain is the foundation for a fast, efficient, and interconnected set of activities that cut across the entire product or service lifecycle (Di Vaio et al., 2023). It is a critical enabler for modern business operations, requiring integrated teams, workflows, information, and technology so companies can achieve peak operational performance (Weisz et al., 2020). The digital supply chain is distinguished by its reliance on digital technologies to enable real-time communication, data sharing, and decision-making (Alshawabkeh et al., 2024). It is intended to be highly responsive to market demand signals, capable of rapid adjustments to change, and oriented towards creating more value for customers through enhanced efficiency and lower costs (Sharabati et al., 2023). The studies suggest that AI's greatest impact on supply chain efficiency has to do with its ability to automate and streamline operations, minimize errors, and make companies more agile and competitive (Garay-Rondero et al., 2020). From a scalability standpoint, the framework asserts that AI is an essential ingredient in enabling the digital supply chain to grow and morph to the dynamic needs of the business and the market. All up, the outlook shared by the authors is one of intensified industrial evolution where AI will provide the tools and capabilities required to convert the dream of a fully functioning digital supply chain into a reality that generates strategic advantage for those organizations that are able to lead the way (Jawabreh et al., 2023). The impact of Artificial Intelligence (AI) on the scene has initiated a profound digital transformation of the digital supply chain, manifested through a blend of easing operational inefficiency and elevating performance (Sharabati et al., 2023). This study recommends that technology such as AI offers the benefits of process efficiency, thereby ensuring competitiveness in the digital supply chain market. Thus, our results provide a critical understanding through which to interpret and guide the impact of AI technology on the core and strategic operations of organizations and highlight the importance of appropriate understanding frameworks such as DOI and TOE (Malik et al., 2021). As a result, this study provides a road map for the national development and prosperity of the enterprise's operational efficiency, through catalyzing advanced digital business applications (Dzwigol et al., 2021). Thus, the findings of these studies encourage enterprises to continue to evolve by developing innovative strategies through leveraging smart digital facilities and process performance, in order to support the "efficiency" of digital supply chain operations and accomplishments (Lee et al., 2023).

2.3 Operational Efficiency

Operational efficiency is a critical convergence point for advanced technologies put to strategic use. This thinking points to the big picture: a complex web of technical AI, business strategy, and connected economy value creation (Hallikas et al., 2021). While operational efficiency is itself a critical KPI (key performance indicator) for AI initiatives, even in the abstract, this AI viewpoint explains how continuous measurement is crucial for mapping additional areas for improvement and making data-driven decisions to continue to improve the performance of the digital supply chain (Hatamlah, Allahham, et al., 2023). The lens of AI on operational efficiency is multi-faceted. The ability to execute processes with as little waste as possible is on the process side. There is also efficiency in how you respond to changes in demand and how well you manage resources more holistically with the decision-making dimension (Lahiri et al., 2022). Responding in sum to all dimensions of operational efficiency can also improve your decision-making which can in turn drive business growth and agility (Al-Banna et al., 2023). Operational efficiency refers to a supply chain management strategy that capitalizes on the strategic deployment of resources to maximize processes and reduce costs while enhancing or maintaining productivity (Benzidia et al., 2021). The roots of operational efficiency run deep in supply chain management. It is absolutely critical to ensure that firms can remain competitive and respond to the demands of the customer in what is an incredibly dynamic market (Adem et al., 2018). Lean principles, for example, have been around for years, but as we have seen, leveraging them with modern technology, like AI and advanced analytics, has helped companies make great strides in increasing operational efficiency across the various functions in their supply chain. In addition to these advancements, we are now seeing AI-driven predictive analytics that has allowed for far more accurate demand forecasting, inventory optimization, and production planning. This has led to drastically lower lead times and inventory carrying costs (Perano et al., 2023). The same can also be said about the degree of coordination and communication that is going on these days between firms and their suppliers and partners. The more these companies can work together, the better they will get at taking costs out of their supply chain and increasing operational efficiency (Belhadi et al., 2019). This will inevitably lead to a smoother supply chain that will allow for firms to be much more responsive rather than reactive to changes in the market. Finally, lastly, the performance metrics and benchmarks that many firms now have in place have guided their continuous improvement initiatives. As demand becomes harder and harder to predict and inventory carrying costs remain an area of great focus for many companies, this capability is key to adapting to the changes in a specific market and continuously improving as a company (Perano et al., 2023). The bottom line is that as the market has become more interconnected, as companies have become faster and faster, and as increased operational efficiency has become the cost of doing business; winning firms today need to be able to do more than just increase operational efficiency. They need to make it a priority.

3. Theoretical Framework

Both are strategic approaches to improving the digital supply chain (Amini & Javid, 2023). They offer a rigorous methodology that enables decision-making to be aligned with the very goals of AI improving operational efficiency and driving business performance. Decision, Operations, and Information (DOI) theory, among other things, is concerned with how to collect, analyze, and present information on which the decision-makers are dependent (Li, 2020). It underlines the requirements for accurate, timely, and actionable information that supports both strategic and operational decisions (Abed, 2020). The application of DOI theory to AI in this context, therefore, means not only making the data that's generated by AI and machine learning systems available but making it more digestible for the decision-maker this could the use of predictive analytics to estimate demand or forecast sales, anomaly detection for identifying issues before they become "real" or employ prescriptive analytics to recommend a course of action as is based on historical patterns and the current state (Skafi et al., 2020). The TOE framework, on the other hand, is a comprehensive model of the links between the technological, organizational, and environmental context of a firm and strategic decision-making by the firm. It's particularly relevant to AI because it helps organizations understand what the economic implications are of new technologies and how these can be accommodated into existing operational scenarios to achieve desired outcomes (Malik et al., 2021). It provides a balanced view of the costs and benefits of these technology investments, considering factors such as return on investment (ROI), payback period, and total cost of ownership (TCO). Together, DOI theory and the TOE framework provide a solid theoretical grounding for the adoption of AI in the digital supply chain (Chittipaka et al., 2023). They provide a guide to selecting, implementing, and managing AI technologies so that they are well-grounded in a firm's strategic objectives and enhance the overall efficiency and profitability of the business (Sayginer & Ercan, 2020).

4. Conceptual Framework and Hypotheses Development

4.1 Scalability and the Digital Supply Chain

Scalability is a key functionality of AI. Scalability allows a system to grow, without degrading performance or increasing downtime. In the digital supply chain, the efficiency of saleable AI is key to scalability as a growth manager (Sarfaraz et al., 2023). As companies grow, their supply chain must grow to support new products, new markets, and new demands from customers. Scalable AI is the digital backbone allowing companies to grow in volume and complexity, without breaking legacy infrastructure (Sarfaraz, 2023). As well as growth, scalability is a border crosser. Whether expanding into new markets or doubling down on existing ones, companies need scalable AI to tie into regional logistics, regional payment gateways, and regional compliance and regulatory mechanisms (Ahmed & MacCarthy, 2023). This scalability allows supply chain operations to ripple seamlessly across the planet. Hence, we proposed the following hypothesis:

H$_1$: *Scalability has a positive impact on Digital Supply Chain*.

4.2 Security and Digital Supply Chain

Security is a critical area in the digital supply chain that deals with sensitive data and a wide range of cyber threats. It has a profound impact on the supply chain. Protecting data and ensuring their integrity is critical (Fernando & Ikhsan, 2023). This requires compliance with multiple security guidelines and a wide range of legal obligations. A prerequisite to building trust is to walk the talk -implementing security measures that ensure that only authorized parties have access to data that was shared, and signal that you think their data security matters. Finally, embracing such a proactive risk detection and mitigation approach is critical to minimizing the negative impacts of such threats on the supply chain and minimizing their duration. As such they offer opportunities to greatly improve business continuity (i.e. how fast you get back to normal from an incident) (Hammi et al., 2023). Incidents mean downtime, and downtime means lost revenue, unhappy customers, and potentially, the loss of those customers. Ensuring a secure supply chain does more than help ensure that you're the company that won't lose your customers' data or impede their ability to run their factories because of a ransomware demand that you can't respond to quickly enough (Alshurideh et al., 2023). A company that can demonstrate that its supply chains are secure not only will differentiate itself from its competitors, but can enjoy other benefits, such as being seen as an easier M&A target, as some activities are secured (by offering the opportunity to jettison and/or share this function), and one that presents some interesting possibilities for strategic partnerships or investments (Weerabahu et al., 2023). The following hypothesis has been proposed

H$_2$: *Security has a positive impact on the Digital Supply Chain.*

4.3 Standardization and Digital Supply Chain

Standardization is at the heart of the digital supply chain, underpinning the efficiency, interoperability, and collaboration that enables it to function (Perano et al., 2023). It allows otherwise siloed systems and processes to communicate and work together by adhering to the same universally recognized protocols and formats. In doing so, it simplifies the management of highly complex supply chains, removes the need for custom integrations every time new applications are added, and ensures information can be easily exchanged among diverse stakeholders (Medyński et al., 2023). It also creates the transparency and accountability needed for a modern, agile supply chain: providing a common language to all involved, and one that supports the tracking and tracing of goods, the monitoring of performance, the rectification of errors, and the resolution of disputes (Mohsen, 2023). In doing so, it supports scalability, allowing organizations to expand globally without having to choose between adding further layers of complexity to their systems and operations or requiring the systems they integrate with to conform to different standards from those they're used to. In short, it's the means by which organizations can give the digital supply chain the cohesion, consistency, and reliability it needs to underpin its vision and strategies (Weerabahu et al., 2023).

H$_3$: *Standardization has a positive impact on the Digital Supply Chain.*

4.4. Mediating Role of Operational Efficiency and Digital Supply Chain

Operational efficiency is the mediating force in the digital supply chain, the connector between an organization's internal processes and the outward customer experience (Deepu & Ravi, 2023). It represents how effectively and productively a business can execute its supply chain activities, weighing the costs of inputs against the value delivered to the customer (Reyes et al., 2023). It's not just about cost reduction, but also about creating value, driving innovation, and maintaining an organization's position in the marketplace (Fu et al., 2023). In the digital supply chain, operational efficiency is manifested in key areas like process optimization, cost reduction, customer satisfaction, agility, and responsiveness (Oubrahim et al., 2023). Automated, streamlined processes and less waste increase the speed at which companies can deliver their products or services, and lend a smooth consistency to the quality of those products or services. This consistent level of quality plays a crucial role in earning and maintaining customer allegiance. Operational efficiency produces the data that helps organizations make strategic decisions. All that savings can be funneled into organizational areas where it will be the most useful and create the most value (Albrakat et al., 2023). It's the linchpin that holds together diverse, specialized components, and it seems that they work together to deliver value to the customer and drive the business forward (Baruffaldi et al., 2020).

This mediator acts as a bridge between operational efficiency and scalability, suggesting that while operational efficiency is a key factor, it is the mediator that facilitates the relationship between these two aspects of the digital supply chain. The theoretical model posits a direct path from operational efficiency to the mediator, and from the mediator to scalability, with the understanding that the effect of operational efficiency on scalability is fully explained by the mediator's influence.

H$_4$: *Operational efficiency positively mediates the relationship with Scalability in the digital supply chain.*

According to (Iris & Lam, 2019), this mediator implies that while operational efficiency is an essential issue, the mediator has an essential role in detecting the impact on security in the digital supply chain. Thuraisingham believes that the impact of operational efficiency on security could be mediated by this mediator factor (Bell et al., 2018). Operational efficiency data was then collected along with mediator and security measures and the hypothesis was tested using empirical data.

H5: *Operational efficiency positively mediates the relationship with Security in the digital supply chain.*

Following the variable of time in varying standardization of digital supply chains should be fully exploited to optimize operational efficiency. Simply improving operational efficiency might drive up standardization; however, increased improvement therein comes not only from operational performance but also from some other variable. This is known as a mediator (Kovács & Falagara Sigala, 2021). The mediates link operational efficiency and standardization, signaling that while operational efficiency is a significant determinant, the mediator is ultimately the key that unlocks the full potential of operational efficiency in standardization for the digital supply chain (Medyński et al., 2023). The theoretical model for this hypothesis includes a direct link from operational efficiency to the mediator, and from the mediator to standardization, with the understanding that the impact of operational efficiency on standardization is fully mediated by the mediator.

H6: *Operational efficiency positively mediates the relationship with Standardization in the digital supply chain.*

Operational efficiency is essential in the digital supply chain, impacting cost structures, customer happiness, agility, data quality, sustainability, and competitive advantage. This efficiency drives down costs and inventory levels by cutting waste and streamlining operations(M. Wang et al., 2020). This in turn reduces the cost of holding goods and improves bargaining power with suppliers and buyers. It leads to faster delivery times as well, which elevates customer satisfaction. Faster, cheaper delivery also carries a competitive advantage in the marketplace. A corollary advantage of optimizing operations is that you're also well-placed to leverage advanced technologies and data analytics (Adeodu et al., 2023). These are typically the product of effective operations. The result is improved data quality, which allows you to make more accurate forecasts and manage inventory better. Operational efficiency is also about cutting waste and reducing energy use. This also lowers carbon footprints and improves environmental performance. The result: a digital supply line that offers better service levels, faster delivery times, and lower costs may be a factor in recruiting and retaining consumers in a highly competitive environment.

H7: *Operational efficiency positively mediates Digital Supply Chain.*

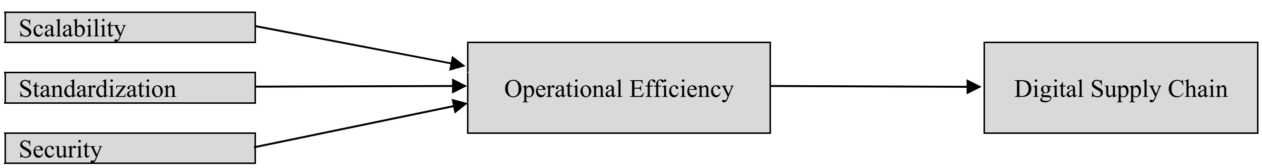

Fig. 1. The proposed theoretical framework

5. Methodology

In this study, to obtain and sample a large number of engineering, electrical, and IT sectors that included a total of 453 facilities were approached by a Jordan Chamber of Industry that holds such facilities (Jordan Chamber of Industry, 2022). A random sample technique was used to get a full industry outlook (Krejcie & Morgan, 1970). For the purposes of this study, the demographic contained the sample size that included 208 managers and executives. By means of a sampling technique such as this, bias was minimized and generalizability to the intended population for the study was ensured. These participants were then provided data gathering tools (e.g. surveys or interviews) to ask if and how operational performance affects supply chain performance in their individual facilities. A sampling technique like this allowed for the bringing together of wide-ranging perspectives, thus adding to the robustness of data obtained during the research.

5.1 Data analysis

SmartPLS software was used for the study. Smart PLS is a variance-based approach and it is particularly useful in the analysis of complex relationships which is often the case in SEM and especially useful in studies with small sample sizes and with non-normal data that do not meet the strict assumptions of traditional covariance-based SEM (Hair, Hult, Ringle, & Sarstedt, 2014). This study's data analysis was conducted in two stages. The measurement model was evaluated at stage one in order to confirm the validity and reliability of the study's constructs. Where necessary, the discriminant validity of constructs ensuring that each represents a distinct underlying concept was tested. The internal consistency of the items for each construct was assessed using Cronbach's alpha and average variance extracted (AVE) as recommended by the authors of the model (Hair et al., 2017). Then, at stage two, the structural model analysis was used to confirm the hypothesized relationship between the variables. Path coefficients were evaluated to determine the strength and direction of the links hypothesized in the conceptual framework. Using bootstrapping, the significance of indirect effects and confidence intervals for path coefficients were computed (Henseler, Ringle, & Sarstedt, 2015). Table 1 presents a comprehensive analysis of the constructs utilized in the study. The constructs exhibit strong psychometric properties across various dimensions. The values of the factor loadings of the items range between 0.574 and 0.893, signifying that all items have strong associations with the constructs. They thus offer robust measurement validity. The constructs also exhibit strong internal consistencies. The Cronbach's alpha coefficients range between 0.745 and 0.912 for the constructs. These values are above the acceptable threshold level of 0.7, suggesting that the measurement instruments are reliable. The composite reliability scores are greater than the acceptable limit within the range of 0.832– 0.924, further supporting the reliability of the constructs. The AVE values exceed the threshold of 0.5 for all the constructs, suggesting adequate convergent validity. Measures of digital supply chain and scalability have particularly strong psychometric properties, with AVE values of 0.598 and 0.711, respectively. In sum, these findings underscore the robustness of the measurement model. They instill confidence in the validity and reliability of the study's findings.

Table 1
Factor loadings

Constructs	Items	Factor loadings	Cronbach's Alpha	C.R.	(AVE)
Digital Supply Chain	DSC-1	0.811	0.912	0.91	0.598
	DSC -2	0.790			
	DSC -3	0.819			
	DSC -4	0.849			
	DSC -5	0.786			
	DSC -6	0.745			
	DSC -7	0.649			
	DSC -8	0.713			
	DSC -9	0.754			
Scalability	SCA-1	0.839	0.889	0.924	0.711
	SCA -2	0.832			
	SCA -3	0.868			
	SCA -4	0.833			
	SCA -5	0.893			
Security	SEC-1	0.574	0.849	0.880	0.481
	SEC -2	0.787			
	SEC -3	0.650			
	SEC -4	0.729			
	SEC -5	0.647			
	SEC -6	0.706			
	SEC -7	0.775			
	SEC -8	0.654			
Standardization	STA-1	0.830	0.745	0.832	0.557
	STA-2	0.840			
	STA -3	0.692			
	STA -4	0.598			
Operational efficiency	OPE-1	0.709	0.818	0.870	0.569
	OPE -2	0.815			
	OPE -3	0.807			
	OPE -4	0.759			
	OPE -5	0.712			

5.2 Structural Model

Two common methods through which validity is evaluated in the context of composite constructs are discriminant validity and cross-validation. Initially, HTMT is scrutinized for discriminant validity. The HTMT should be less than .90, originally proposed by (Henseler et al., 2015), and recently endorsed and updated by (Franke & Sarstedt, 2019). Table 2 shows these values: certainly, within acceptable limits, and no one construct is poorly defined relative to the others. At this point, we can conclude we have satisfied the reliability and validity of the measurement model.

Table 2
HTMT

	Scalability	Standardization	Operational efficiency	Security
Scalability				
Standardization	0.731			
Operational efficiency	0.688	0.522		
Security	0.613	0.420	0.604	
Digital Supply Chain	0.670	0.754	0.584	0.565

As shown in the table, the correlation matrix indicates the degree of association among the constructs of scalability, standardization, operational efficiency, security, and digital supply chain. Each cell contains the correlation coefficient between the constructs that correspond with the cell. Analyzing the correlations reported in the above matrix, it can be observed that the constructs are positively correlated, generally with positive but even moderately positive associations among them (Hair et al., 2014), which suggests that they are interrelated within the conceptual framework. In particular, scalability is significantly related to standardization ($r = 0.731$), operational efficiency ($r = 0.688$), and security ($r = 0.613$), demonstrating moderate to strong positive correlations. Standardization has moderately positive associations with operational efficiency ($r = 0.522$) and security ($r = 0.42$). The construct of operational efficiency shows a moderate positive correlation with security ($r = 0.604$) and a moderately positive correlation with digital supply chain ($r = 0.584$).

These findings are indicative that the constructs are connected in a web of relationships and may potentially be influencing each other within the context of this study. For instance, improvements in scalability may influence not just standardization, but also operational efficiency and security across the supply chain. Similarly, improvements in operational efficiency would likely impact security and the overall digital supply chain.

Table 3
Fronell-Larcker

	Scalability	Standardization	Operational efficiency	Security	Digital Supply Chain
Scalability	**0.670**				
Standardization	0.690	**0.833**			
Operational efficiency	0.575	0.459	**0.759**		
Security	0.493	0.369	0.524	**0.745**	
Digital Supply Chain	0.634	0.690	0.509	0.516	**0.770**

We report the Fornell-Larcker criterion results in Table 3, along the diagonal the square roots of the AVE of each construct and its correlations with all other constructs are compared. As seen in the table, the square root of the AVE of each construct is higher than the correlations between the construct and all other constructs, indicating that it shares more variance with its own indicators than with other constructs, supporting discriminant validity. For example, the square root of the AVE of Scalability is 0.670, which is higher than its correlations with Standardization (0.690), Operational Efficiency (0.575), Security (0.493), and Digital Supply Chain (0.634). The same is true for all other constructs; that is, the square root of the AVE is consistently higher than the correlations with constructs, supporting discriminant validity]. These findings suggest that the constructs are distinct in this model and measure different underlying concepts supporting the validity of the measurement model because the Fornell-Larcker criterion assures that the constructs adequately represent their intended constructs and do not overlap significantly with other constructs in the model.

Table 4
Adjusted R-Square

Variable	**R^2**	**R^2 Adjusted**
Digital Supply Chain	0.625	0.617

5.3 Demographic information of respondents

Table 5 presents a complete picture of the demographic characteristics of the study sample, helping to enrich the content of the sample. The data show that male respondents are by far the most prevalent in the sample (72.40 percent versus 27.60 percent female). In terms of age distribution, most of the respondents belong to the 35-less than 45 groups (44.16 percent), followed by the 45 and above group (29.87 percent). Educationally, a large proportion hold an undergraduate degree (59.09 percent) though a significant number have a postgraduate degree (28.57 percent). Duration-wise, wide experience is a feature in the responses, with most of the respondents having 15 less than 20 years of service (33.77 percent). Finally, for their specialization, a majority of the respondents have specialized in Business Administration – M.B.A (53.57 percent). Such a demographic profile is valuable to understanding the perspective and background of the respondents and enriching the interpretation and the generalizability of the findings of this study.

Table 5
Demographic information of respondents

Characteristic	**Frequency**	**Percentage**	**Characteristic**	**Frequency**	**Percentage**
Gender			**Specialization**		
Male	151	72%	Business Administration	112	53%
Female	57	27%	Accounting	45	21%
Age			Social sciences	39	18%
less than 27	19	9%	Other	12	5%
27-less than 35	35	16%	**Experience**		
35-less than 45	92	44%	less than 10	23	11%
45 and above	63	29%	10-less than 15	38	18%
Education			15-less than 20	70	33%
Diploma	26	12%	20-less than 25	50	24%
Undergraduate degree	123	59%	25 and above	26	12%
Postgraduate degree (Master/PhD)	60	28%			

The demographic profile depicted in Table 4 reflects a predominantly male sample, comprising 72.40% of respondents, while females represent 27.60%. The age distribution indicates a significant presence of respondents aged 35 to 45 (44.16%) and 45 and above (29.87%), suggesting a mature workforce. Educationally, a majority hold undergraduate degrees (59.09%), with a substantial portion possessing postgraduate degrees (28.57%), indicating a highly educated cohort. Professionally, respondents exhibit diverse experience levels, with a significant proportion having 15 to less than 20 years of experience (33.77%). Regarding specialization, Business Administration emerges as the dominant field (53.57%), followed by accounting (21.75%) and Social Sciences (18.83%). These demographic insights offer a nuanced understanding of the sample composition, facilitating contextualized interpretations of study findings and enhancing the study's applicability across different segments of the workforce.

5.3 Hypotheses Testing

In examining the path coefficient in the structural model, the PLS Algorithm function was applied. The path coefficient in the structural model is analogous to the usual beta weight in a standard regression analysis model of the SmartPLS 3.0 model. The estimated path coefficients range from -1 to +1 and represent strongly negative or strongly positive associations, respectively. A path coefficient near zero (0) implies no relationship; as shown in Table 6, the path coefficient, standard error, T-value, P-value, and significance level of the analysis were also considered in order to ensure the statistical significance of the relationship.

Table 6
Hypotheses testing estimates

Hypo	Relationships	Std. Beta	Std. Error	t-Value	P-Values	Decision
H1	Scalability →Digital Supply Chain	0.445	0.052	7.725	0.000	Supported
H2	Standardization → Digital Supply Chain	0.126	0.062	2.138	0.034	Supported
H3	Security → Digital Supply Chain	0.197	0.055	3.747	0.000	Supported
H4	Operational efficiency→ Digital Supply Chain	0.110	0.045	2.510	0.011	Supported
H5	Scalability → Operational efficiency → Digital Supply Chain	0.141	0.052	2.844	0.004	Supported
H6	Standardization → Operational efficiency → Digital Supply Chain	-0.087	0.041	2.180	0.031	Supported
H7	Security → Operational efficiency → Digital Supply Chain	0.141	0.044	3.177	0.002	Supported

6. Conclusion

This study presents, for the first time, a synthesis of practical insights and theoretical underpinnings that together offer a comprehensive understanding of an emerging digital supply chain landscape within the engineering, electrical, and information technology sectors in Jordan. The practical implications highlight the importance of operational efficiency, scalability, standardization, and security that drive supply chain performance and organizational success. The results of this study show that there is a close connection between artificial intelligence and digital supply chains in Jordanian industrial institutions (Ali et al., 2023). This is due to the urgent need for this sector to keep pace with the huge developments taking place in this sector, which is of importance in enhancing the competitive advantage between the various industrial sectors and which enhances the principle of efficiency and effectiveness in Its work, in addition to that, is to enhance and transfer the level of these institutions from being local institutions to international companies competing in the local market (Dubey et al., 2020). According to (Hatamlah, Allan, et al., 2023), adopting artificial intelligence will enhance the company's performance at the general level of the organization and will enhance the performance of suppliers cooperating with those companies. It also confirms the criticality of operational considerations in the mitigation of transaction cost, optimization of resource allocation, and development of competitive advantage that is implied in Transaction Cost Economics (TCE) theory and Resource-Based View (RBV) The examination of these practical implications through each of the theoretical frameworks suggests that organizations that effectively align their operational strategy with these theoretical considerations will be positioned to strategically navigate the emerging digital supply chain landscape, achieving greater agility, resilience and enhanced responsiveness to market dynamics. The demographic insights that are included in this research offer a rich context that organizations can use to tailor their supply chain initiatives to the diverse needs and backgrounds of industry professionals. The deep theoretical grounding of the contributions of this research provides strong tethers to the broader literature on supply chain management, allowing other researchers to more confidently trace these emergent themes forward and the theoretical nuances that were identified provide a number of fresh ideas that are ripe for future consideration. In the end, with these insights and contributions, this research should serve as a reminder that as the growing wave of digitalization and interconnectivity forces organizations to increasingly become "part of the machine", the insights of theory still very much keep the "engine" in "engineers".

This study, firmly rooted in DOI theory, stresses the central importance of such issues as operational efficiency, scalability, standardization, and security in increasing the ability to adapt and assimilate digital technologies within the supply chain. Through the tenets of innovation diffusion and adoption, our alignment with DOI theory underscores that such is necessary as organizations navigate the intricacies of the integration of technologies and work to develop sustainable value creation. Furthermore, the TOE framework allows for an expansive viewpoint that makes it very clear the outcomes of the supply chain are shaped by the interplay of technological innovation, organizational capabilities, and environmental conditions. The empirical findings of the current research confirm the TOE framework's emphasis on such issues as organizational readiness, technological infrastructure, and the context of external influences in determining the success of digital supply chain initiatives. By drawing from DOI theory and the TOE framework, firms can, thus, create strategies that are particularly tailored, blending both the commonalities of digital technologies and the unique challenges and opportunities that lie within their operational environments, allowing these firms to achieve the innovation afforded. Such an interdisciplinary strategy not only deepens our theoretical comprehension of digital supply chains but also affords practitioners an insightful roadmap for addressing and overcoming the thorny, multifaceted challenges of digital transformation as they are encountered in organizations today.

References

Abed, S. S. (2020). Social commerce adoption using TOE framework: An empirical investigation of Saudi Arabian SMEs. *International Journal of Information Management*, *53*(October 2019), 102118. https://doi.org/10.1016/j.ijinfomgt.2020.102118

Adem, S. Al, Childerhouse, P., Egbelakin, T., Wang, B., Teerlink, M., Tabassum, R., … Verma, S. (2018). Big data analytics and artificial intelligence pathway to operational performance under the effects of entrepreneurial orientation and environmental dynamism: A study of manufacturing organisations. *Industrial Marketing Management*, *226*(0123456789), 3–5. https://doi.org/10.1016/j.ijpe.2019.107599

Adeodu, A., Maladzhi, R., Kana-Kana Katumba, M. G., & Daniyan, I. (2023). Development of an improvement framework for warehouse processes using lean six sigma (DMAIC) approach. A case of third party logistics (3PL) services. *Heliyon*, *9*(4), e14915. https://doi.org/10.1016/j.heliyon.2023.e14915

Ahmed, W. A. H., & MacCarthy, B. L. (2023). Blockchain-enabled supply chain traceability – How wide? How deep? *International Journal of Production Economics*, *263*(April), 108963. https://doi.org/10.1016/j.ijpe.2023.108963

Al-Banna, A., Rana, Z. A., Yaqot, M., & Menezes, B. (2023). Interconnectedness between Supply Chain Resilience, Industry 4.0, and Investment. *Logistics*, *7*(3). https://doi.org/10.3390/logistics7030050

Alazab, M. (2024). *Industry 4 . 0 Innovation : A Systematic Literature Review on the Role of Blockchain Technology in Creating Smart and Sustainable Manufacturing Facilities*.

Albrakat, N. S. A., Al-Hawary, S. I. S., & Muflih, S. M. (2023). Green supply chain practices and their effects on operational performance: An experimental study in Jordanian private hospitals. *Uncertain Supply Chain Management*, *11*(2), 523–532. https://doi.org/10.5267/j.uscm.2023.2.012

Ali, A. A. A., Udin, Z. B. M., & Abualrejal, H. M. E. (2023). *The Impact of Artificial Intelligence and Supply Chain Resilience on the Companies Supply Chains Performance: The Moderating Role of Supply Chain Dynamism BT - International Conference on Information Systems and Intelligent Applications* (M. Al-Emran, M. A. Al-Sharafi, & K. Shaalan, Eds.). Cham: Springer International Publishing.

Alshawabkeh, R. O., Abu Rumman, A. R., & Al-Abbadi, L. H. (2024). The nexus between digital collaboration, analytics capability and supply chain resilience of the food processing industry in Jordan. *Cogent Business and Management*, *11*(1). https://doi.org/10.1080/23311975.2023.2296608

Alshurideh, M. T., Alquqa, E. K., Alzoubi, H. M., Al Kurdi, B., & Hamadneh, S. (2023). The effect of information security on e-supply chain in the UAE logistics and distribution industry. *Uncertain Supply Chain Management*, *11*(1), 145–152. https://doi.org/10.5267/j.uscm.2022.11.001

Amini, M., & Javid, N. J. (2023). A Multi-Perspective Framework Established on Diffusion of Innovation (DOI) Theory and Technology, Organization and Environment (TOE) Framework Toward Supply Chain Management System Based on Cloud Computing Technology for Small and Medium Enterprises. *International Journal of Information Technology and Innovation Adoption*, *11*(8), 1217–1234.

Andiyappillai, N. (2019). Standardization of System Integrated Solutions in Warehouse Management Systems (WMS) Implementations. *International Journal of Computer Applications*, *178*(13), 6–11. https://doi.org/10.5120/ijca2019918891

Baruffaldi, G., Accorsi, R., Manzini, R., & Ferrari, E. (2020). Warehousing process performance improvement: a tailored framework for 3PL. *Business Process Management Journal*, *26*(6), 1619–1641. https://doi.org/10.1108/BPMJ-03-2019-0120

Belhadi, A., Zkik, K., Cherrafi, A., Yusof, S. M., & El fezazi, S. (2019). Understanding Big Data Analytics for Manufacturing Processes: Insights from Literature Review and Multiple Case Studies. *Computers and Industrial Engineering*, *137*(October 2018), 106099. https://doi.org/10.1016/j.cie.2019.106099

Bell, D. R., Gallino, S., & Moreno, A. (2018). Offline showrooms in omnichannel retail: Demand and operational benefits. *Management Science*, *64*(4), 1629–1651. https://doi.org/10.1287/mnsc.2016.2684

Benzidia, S., Makaoui, N., & Bentahar, O. (2021). The impact of big data analytics and artificial intelligence on green supply chain process integration and hospital environmental performance. *Technological Forecasting and Social Change*, *165*. https://doi.org/10.1016/j.techfore.2020.120557

Cai, F., Correll, J. M., Lee, S. H., Lim, Y., Bothra, V., Zhang, Z., … Lu, W. D. (2019). A fully integrated reprogrammable memristor–CMOS system for efficient multiply–accumulate operations. *Nature Electronics*, *2*(7), 290–299. https://doi.org/10.1038/s41928-019-0270-x

Chittipaka, V., Kumar, S., Sivarajah, U., Bowden, J. L. H., & Baral, M. M. (2023). Blockchain Technology for Supply Chains operating in emerging markets: an empirical examination of technology-organization-environment (TOE) framework. *Annals of Operations Research*, *327*(1), 465–492. https://doi.org/10.1007/s10479-022-04801-5

Deepu, T. S., & Ravi, V. (2023). A review of literature on implementation and operational dimensions of supply chain digitalization: Framework development and future research directions. *International Journal of Information Management Data Insights*, *3*(1), 100156. https://doi.org/10.1016/j.jjimei.2023.100156

Dubey, R., Gunasekaran, A., Childe, S. J., Bryde, D. J., Giannakis, M., Foropon, C., … Hazen, B. T. (2020). Big data analytics and artificial intelligence pathway to operational performance under the effects of entrepreneurial orientation and environmental dynamism: A study of manufacturing organisations. *International Journal of Production Economics*, *226*, 107599.

Dzwigol, H., Trushkina, N., & Kwilinski, A. (2021). the Organizational and Economic Mechanism of Implementing the Concept of Green Logistics. *Virtual Economics*, *4*(2), 41–75. https://doi.org/10.34021/ve.2021.04.02(3)

Elijah, O., Rahman, T. A., Orikumhi, I., Leow, C. Y., & Hindia, M. N. (2018). An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. *IEEE Internet of Things Journal*, *5*(5), 3758–3773. https://doi.org/10.1109/JIOT.2018.2844296

Etemadi, N., Borbon-Galvez, Y., Strozzi, F., & Etemadi, T. (2021). Supply chain disruption risk management with blockchain: A dynamic literature review. *Information (Switzerland)*, *12*(2), 1–25. https://doi.org/10.3390/info12020070

Fernando, Y., & Ikhsan, R. B. (2023). A Data-Driven Supply Chain: Marketing Data Sharing, Data Security, and Digital

Technology Adoption to Predict Firm's Resilience. *Binus Business Review*, *14*(1), 99–109. https://doi.org/10.21512/bbr.v14i1.9305

Franke, G., & Sarstedt, M. (2019). Heuristics versus statistics in discriminant validity testing: a comparison of four procedures. *Internet Research*.

Fu, S., Liu, J., Tian, J., & Peng, J. (2023). *Impact of Digital Economy on Energy Supply Chain Efficiency :* 1–21.

Garay-Rondero, C. L., Martinez-Flores, J. L., Smith, N. R., Caballero Morales, S. O., & Aldrette-Malacara, A. (2020). Digital supply chain model in Industry 4.0. *Journal of Manufacturing Technology Management*, *31*(5), 887–933. https://doi.org/10.1108/JMTM-08-2018-0280

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2014). A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). Sage Publications. *European Journal of Tourism Research*, *6*(2), 211–213.

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

Hammi, B., Zeadally, S., & Nebhen, J. (2023). Security Threats, Countermeasures, and Challenges of Digital Supply Chains. *ACM Computing Surveys*, *55*(14 S). https://doi.org/10.1145/3588999

Hatamlah, H., Allahham, M., Abu-AlSondos, I. A., Al-junaidi, A., Al-Anati, G. M., & Al-Shaikh, and M. (2023). The Role of Business Intelligence adoption as a Mediator of Big Data Analytics in the Management of Outsourced Reverse Supply Chain Operations. *Applied Mathematics and Information Sciences*, *17*(5), 897–903. https://doi.org/10.18576/AMIS/170516

Hatamlah, H., Allan, M., Abu-Alsondos, I., Shehadeh, M., & Allahham, M. (2023). The role of artificial intelligence in supply chain analytics during the pandemic. *Uncertain Supply Chain Management*, *11*(3), 1175–1186. https://doi.org/10.5267/j.uscm.2023.4.005

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*(1), 115–135.

Iris, Ç., & Lam, J. S. L. (2019). A review of energy efficiency in ports: Operational strategies, technologies and energy management systems. *Renewable and Sustainable Energy Reviews*, *112*, 170–182. https://doi.org/10.1016/j.rser.2019.04.069

Jawabreh, O., Baadhem, A. M., Ali, B. J. A., Atta, A. A. B., Ali, A., Al-Hosaini, F. F., & Allahham, M. (2023). The Influence of Supply Chain Management Strategies on Organizational Performance in Hospitality Industry. *Applied Mathematics and Information Sciences*, *17*(5), 851–858. https://doi.org/10.18576/AMIS/170511

Jordan Chamber of Industry. (2022). No Title. Retrieved from

https://www.jci.org.jo/Chamber/Sector/80066/- The engineering, electrical, and information technology industries.

Katsaliaki, K., Galetsi, P., & Kumar, S. (2022). Supply chain disruptions and resilience: a major review and future research agenda. In *Annals of Operations Research* (Vol. 319). https://doi.org/10.1007/s10479-020-03912-1

Kim, J. S., & Shin, N. (2019). The impact of blockchain technology application on supply chain partnership and performance. *Sustainability (Switzerland)*, *11*(21). https://doi.org/10.3390/su11216181

Kovács, G., & Falagara Sigala, I. (2021). Lessons learned from humanitarian logistics to manage supply chain disruptions. *Journal of Supply Chain Management*, *57*(1), 41–49. https://doi.org/10.1111/jscm.12253

Krejcie, R. V, & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement*, *30*(3), 607–610.

Lahiri, M. M., Sarkar, S., & Bhargava, M. (2022). The Role of 3rd Party Logistics In Bringing Efficiency & Effectiveness among their Distribution Centers. *Academy of Marketing Studies Journal*, *26*(6), 1–7.

Lee, K. L., Wong, S. Y., Alzoubi, H. M., Al Kurdi, B., Alshurideh, M. T., & El Khatib, M. (2023). Adopting smart supply chain and smart technologies to improve operational performance in manufacturing industry. *International Journal of Engineering Business Management*, *15*, 1–14. https://doi.org/10.1177/18479790231200614

Li, J. C. F. (2020). Roles of individual perception in technology adoption at organization level: Behavioral model versus toe framework. *Journal of System and Management Sciences*, *10*(3), 97–118. https://doi.org/10.33168/JSMS.2020.0308

Malik, S., Chadhar, M., & Chetty, M. (2021). Factors affecting the organizational adoption of blockchain technology: An Australian perspective. *Proceedings of the Annual Hawaii International Conference on System Sciences*, *2020-Janua*, 5597–5606. https://doi.org/10.24251/hicss.2021.680

Medyński, D., Bonarski, P., Motyka, P., Wysoczański, A., Gnitecka, R., Kolbusz, K., … Machado, J. (2023). Digital Standardization of Lean Manufacturing Tools According to Industry 4.0 Concept. *Applied Sciences (Switzerland)*, *13*(10). https://doi.org/10.3390/app13106259

Mohsen, B. M. (2023). Developments of Digital Technologies Related to Supply Chain Management. *Procedia Computer Science*, *220*, 788–795. https://doi.org/10.1016/j.procs.2023.03.105

Nandi, M. L., Nandi, S., Moya, H., & Kaynak, H. (2020). Blockchain technology-enabled supply chain systems and supply chain performance: a resource-based view. *Supply Chain Management*, *25*(6), 841–862. https://doi.org/10.1108/SCM-12-2019-0444

Nasir, M. H., Arshad, J., Khan, M. M., Fatima, M., Salah, K., & Jayaraman, R. (2022). Scalable blockchains — A systematic review. *Future Generation Computer Systems*, *126*, 136–162. https://doi.org/10.1016/j.future.2021.07.035

Nurgazina, J., Pakdeetrakulwong, U., Moser, T., & Reiner, G. (2021). Distributed ledger technology applications in food supply chains: A review of challenges and future research directions. *Sustainability (Switzerland)*, *13*(8). https://doi.org/10.3390/su13084206

Olan, F., Liu, S., Suklan, J., Jayawickrama, U., & Arakpogun, E. O. (2022). The role of Artificial Intelligence networks in sustainable supply chain finance for food and drink industry. *International Journal of Production Research*, *60*(14), 4418-4433. https://doi.org/10.1080/00207543.2021.1915510

Oubrahim, I., Sefiani, N., & Happonen, A. (2023). The Influence of Digital Transformation and Supply Chain Integration on Overall Sustainable Supply Chain Performance: An Empirical Analysis from Manufacturing Companies in Morocco. *Energies*, *16*(2). https://doi.org/10.3390/en16021004

Perano, M., Cammarano, A., Varriale, V., Del Regno, C., Michelino, F., & Caputo, M. (2023). Embracing supply chain digitalization and unphysicalization to enhance supply chain performance: a conceptual framework. In *International Journal of Physical Distribution and Logistics Management* (Vol. 53). https://doi.org/10.1108/IJPDLM-06-2022-0201

Reyes, J., Mula, J., & Díaz-Madroñero, M. (2023). Development of a conceptual model for lean supply chain planning in industry 4.0: multidimensional analysis for operations management. *Production Planning and Control*, *34*(12), 1209–1224. https://doi.org/10.1080/09537287.2021.1993373

Salhab, H. A., Allahham, M., Abu-Alsondos, I. A., Frangieh, R. H., Alkhwaldi, A. F., & Ali, B. J. A. (2023). Inventory competition, artificial intelligence, and quality improvement decisions in supply chains with digital marketing. *Uncertain Supply Chain Management*, *11*(4), 1915–1924. https://doi.org/10.5267/j.uscm.2023.8.009

Sarfaraz, A. (2023). *Blockchain-Coordinated Frameworks for Scalable and Secure Supply Chain Networks*.

Sarfaraz, Aaliya, Chakrabortty, R. K., & Essam, D. L. (2023). Reputation based proof of cooperation: an efficient and scalable consensus algorithm for supply chain applications. *Journal of Ambient Intelligence and Humanized Computing*, *14*(6), 7795–7811. https://doi.org/10.1007/s12652-023-04592-y

Sayginer, C., & Ercan, T. (2020). Understanding Determinants of Cloud Computing Adoption Using an Integrated Diffusion of Innovation (Doi)-Technological, Organizational and Environmental (Toe) Model. *Humanities & Social Sciences Reviews*, *8*(1), 91–102. https://doi.org/10.18510/hssr.2020.8115

Sharabati, A. A., Allahham, M., Yahiya, A., Ahmad, B., & Sabra, S. (2023). *Effects of artificial integration and big data analysis on economic viability of solar microgrids : mediating role of cost benefit analysis*. *Operational Research in Engineering Sciences: Theory and Applications*, *6*(3), 360–379.

Skafi, M., Yunis, M. M., & Zekri, A. (2020). Factors influencing SMEs' adoption of cloud computing services in Lebanon: An empirical analysis using TOE and contextual theory. *IEEE Access*, *8*, 79169–79181. https://doi.org/10.1109/ACCESS.2020.2987331

Sobb, T., Turnbull, B., & Moustafa, N. (2020). Supply chain 4.0: A survey of cyber security challenges, solutions and future directions. *Electronics (Switzerland)*, *9*(11), 1–31. https://doi.org/10.3390/electronics9111864

Solfa, F. D. G. (2022). Impacts of Cyber Security and Supply Chain Risk on Digital Operations: Evidence from the Pharmaceutical Industry. *International Journal of Technology, Innovation and Management (IJTIM)*, *2*(2), 18–32. https://doi.org/10.54489/ijtim.v2i2.98

Thakur, S., & Breslin, J. G. (2020). Scalable and secure product serialization for multi-party perishable good supply chains using blockchain. *Internet of Things (Netherlands)*, *11*, 100253. https://doi.org/10.1016/j.iot.2020.100253

Toorajipour, R., Sohrabpour, V., Nazarpour, A., Oghazi, P., & Fischl, M. (2021). Artificial intelligence in supply chain management: A systematic literature review. *Journal of Business Research*, *122*(May 2020), 502–517. https://doi.org/10.1016/j.jbusres.2020.09.009

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, *39*(2), 273–315. https://doi.org/10.1111/j.1540-5915.2008.00192.x

Wang, M., Wang, B., & Abareshi, A. (2020). Blockchain technology and its role in enhancing supply chain integration capability and reducing carbon emission: A conceptual framework. *Sustainability (Switzerland)*, *12*(24), 1–17. https://doi.org/10.3390/su122410550

Wang, X., Pan, Z., Li, Z., Ji, W., & Yang, F. (2019). Adaptive information sharing approach for crowd networks based on two stage optimization. *International Journal of Crowd Science*, *3*(3), 284–302. https://doi.org/10.1108/IJCS-09-2019-0020

Weerabahu, W. M. S. K., Samaranayake, P., Nakandala, D., & Hurriyet, H. (2023). Digital supply chain research trends: a systematic review and a maturity model for adoption. *Benchmarking*, *30*(9), 3040–3066. https://doi.org/10.1108/BIJ-12-2021-0782

Weisz, E., Herold, D. M., & Kummer, S. (2020). Revisiting the bullwhip effect: how can AI smoothen the bullwhip phenomenon? *International Journal of Logistics Management*, *34*(7), 98–120. https://doi.org/10.1108/IJLM-02-2022-0078