International Journal of Applied Business & International Management (IJABIM)
Vol. 10, No. 2, pp.193-211, August, 2025
E-ISSN: 2621-2862 P-ISSN: 2614-7432
https://www.ejournal.aibpmjournals.com/index.php/IJABIM

Instrumented Supply Chain and Interconnected Supply Chain on Operational Performance: The Role of Smart Technology

Zilnia Putri[1], Muhammad Ali Fikri[1*]
[1]Universitas Ahmad Dahlan, Jl. Kapas No.9, Semaki, Kec. Umbulharjo, Yogyakarta City, Daerah Istimewa Yogyakarta 55166
*Corresponding Email: muhammad.fikri@mgm.uad.ac.id

ARTICLE INFORMATION

Publication information

Research article

HOW TO CITE
Putri, Z., & Fikri, M. A. (2025). Instrumented supply chain and interconnected supply chain on operational performance: The role of smart technology. *International Journal of Applied Business & International Management*, *10*(2), 193-211.

DOI:
https://doi.org/10.32535/ijabim.v10i2.3995

Received: 17 June 2025
Accepted: 19 July 2025
Published: 20 August 2025

ABSTRACT

Transformation in the Industry 4.0 era has pushed manufacturing companies to adopt the latest technologies in their supply chains to enhance operational efficiency and productivity. This study aims to examine the influence of instrumented supply chain and interconnected supply chain on operational performance, with smart technology as a mediating variable. Data were collected using a purposive sampling method from 100 respondents of micro, small, and medium enterprises (MSMEs) in the manufacturing sector in Yogyakarta. The analysis was conducted using Smart PLS 4.0 software. The results reveal that the instrumented supply chain significantly influences operational performance (β = 0.546, p = 0.000) and smart technology (β = 0.515, p = 0.000). In contrast, the interconnected supply chain does not significantly affect operational performance (β = 0.052, p = 0.622), but has a significant effect on smart technology (β = 0.288, p = 0.011). Smart technology also significantly improves operational performance (β = 0.304, p = 0.014) and mediates the effect of instrumented supply chain on operational performance (β = 0.156, p = 0.046). However, it does not mediate the effect of the interconnected supply chain on operational performance (p = 0.071). These findings highlight the strategic role of digital instrumentation and smart technology in enhancing supply chain-driven performance.

Keywords: Instrumented Supply Chain; Interconnected Supply Chain; Operational Performance; Smart Technology; Supply Chain Management

INTRODUCTION

Operational performance is a key indicator in determining a company's sustainability and competitive strength, particularly in the manufacturing industry, which involves complex production processes and multiple parties within the supply chain (AlMulhim, 2021). Operational performance is defined as the level of efficiency in business processes, including the management of resources, conversion of inputs into outputs, and the achievement of optimal results in production and distribution (Alshurideh et al., 2023a). The primary objective of operational performance is to increase productivity, service quality, and profitability through effective operations (Kukanja & Planinc, 2020). Although operational performance serves as an effective goal for companies, various challenges such as demand-supply imbalances, stock surpluses or shortages, and delivery delays are still frequently encountered by the manufacturing sector (Gupta et al., 2019). To address these challenges and adapt to the digital era, companies need to adopt the concepts of the instrumented supply chain and the interconnected supply chain as innovative solutions for improving operational performance (Alzoubi et al., 2022).

The instrumented supply chain is an evolution of the smart supply chain concept that integrates sensor technology, software, and data analytics to monitor, control, and optimize the flow of goods and information (Cahyaningratri & Naylah, 2023). With accurate instrumentation, companies can enhance supply chain visibility, reduce uncertainty, and accelerate data-driven decision-making (Butner, 2010). Several studies have shown that adopting an instrumented supply chain has a significant impact on operational performance, particularly in improving efficiency, accuracy, and cost savings (Alzoubi et al., 2022; Hanaysha & Alzoubi, 2022).

The interconnected supply chain emphasizes strong and integrated relationships among various actors in the supply chain through internet-based platforms and modern communication technologies (Guo et al., 2022; Hanaysha & Alzoubi, 2022). This interconnected approach promotes increased collaboration, real-time information sharing, and better coordination in resource management. The interconnected supply chain has been proven to enhance functionality, flexibility, and operational performance (Lee et al., 2023).

The development of smart technologies such as artificial intelligence (AI), the internet, big data analytics, and blockchain supports the implementation of instrumented and interconnected supply chains (Alshurideh et al., 2023b; Wu et al., 2016). These technologies act as mediators that bridge the influence of instrumented and interconnected supply chains on operational performance. By integrating these technologies, companies can optimize resource utilization, respond more rapidly to market dynamics, and increase efficiency throughout the entire supply chain (Mehmood, 2021).

Based on the literature, the relationship between instrumented supply chains and interconnected supply chains on operational performance can be strengthened through the mediating role of smart technology. This conceptual model is supported by research from Hanaysha and Alzoubi (2022), which shows that the use of smart technology in the supply chain directly contributes to improving operational performance. Although the adoption of smart technology offers great potential, its implementation also brings challenges in terms of social and environmental sustainability that must be anticipated to avoid negative impacts (Jaekel, 2020).

In Indonesia, particularly in Yogyakarta, the manufacturing industry sector contributes 12.07 percent to the regional gross domestic product. In the first quarter of 2024, it experienced growth of 5.02% (Central Agency of Statistics of DI Yogyakarta Province [BPS Provinsi DIY], 2024). The manufacturing industry in this region is dominated by MSMEs with an orientation towards creative and cultural products, making it different from the structure of the manufacturing industry in other regions of Indonesia. However, the dominance of MSMEs also brings challenges, especially in terms of digitalization and low supply chain integration.

The main problems faced by manufacturing companies in Yogyakarta include limitations in the use of smart technology, minimal integration of information systems in the supply chain (interconnected supply chain), and low utilization of monitoring devices and sensors (instrumented supply chain) in the production and distribution processes. As stated by Shao et al. (2021), challenges in implementing smart technology in the MSMEs manufacturing sector are generally caused by limited resources, a lack of digital literacy, and a strong reliance on manual processes.

In addition, Gupta et al. (2019) emphasized that the success of supply chain digitalization is highly dependent on the alignment between technology, business processes, and organizational competencies. In Yogyakarta, the integration of information systems among supply chain actors is still partial and not yet optimal. This condition hinders the formation of an interconnected supply chain capable of sharing information in real time, even though accurate and fast information is crucial for strategic decision-making in facing market dynamics and supply disruptions (Ivanov & Keskin, 2023).

Furthermore, Ramakrishna et al. (2023) emphasized the importance of smart technology as a mediating variable that can bridge the relationship between technology-based supply chain infrastructure (such as instrumented and interconnected supply chains) and improved operational performance. However, to date, there has been very limited empirical research that specifically examines the mediation mechanism in the context of MSMEs in the manufacturing sector in Yogyakarta. This gap indicates the need for in-depth studies that adapt technological approaches to the local context and the unique characteristics of MSMEs.

A study that integrates the instrumented supply chain, interconnected supply chain, and smart technology approaches is essential to identify appropriate technology adoption models to improve the efficiency, productivity, and competitiveness of the culture-based manufacturing sector in Yogyakarta. Thus, this research can contribute both theoretically, in developing a mediation model, and practically, in providing recommendations for digital transformation strategies for the manufacturing industry in the region.

This study aims to analyze the consistency of the influence of instrumented supply chains and interconnected supply chains on operational performance with the role of smart technology as a mediating variable. This study is expected to provide theoretical contributions to the development of technology-based supply chain literature and practical contributions for companies in designing effective digitalization strategies. Academically, this study fills a gap in the literature on the complex relationship between digital supply chains and operational performance. Practically, the results of the study can serve as a strategic guide for manufacturing companies in Yogyakarta in implementing smart supply chains to increase competitiveness in the Industrial Era 4.0.

LITERATURE REVIEW

Instrumented Supply Chain

An instrumented supply chain is a supply chain system that utilizes digital technology devices to collect, monitor, and analyze real-time data throughout the supply chain process flow. This system enables high visibility into the movement of goods, operational conditions, and logistics status, thereby increasing the speed of decision-making and the effectiveness of coordination among supply chain actors (Lee et al., 2023). According to Wu et al. (2016), an instrumented supply chain is the fundamental foundation in developing a smart supply chain and provides companies with the ability to access accurate and up-to-date information without relying on manual input. This system integrates data from various points in the supply chain, from production and distribution to end consumers, so that companies have the ability to predict demand, detect disruptions early, and optimize processes.

Interconnected Supply Chain

An interconnected supply chain refers to a supply chain system that is digitally and operationally connected among all parties involved, from raw material suppliers to end customers (Kache & Seuring, 2017). This interconnected supply chain is crucial in building operational resilience, which is the ability to adapt to and recover from various challenges such as pandemics, natural disasters, or geopolitical instability (Ivanov et al., 2018). According to Tiwari et al. (2018), an interconnected supply chain promotes the creation of complete visibility along the supply chain flow, where information about inventory, delivery, and market demand can be shared transparently with all involved partners, enabling companies to minimize errors in decision-making and strengthen collaboration between strategic and operational planning.

Smart Technology

Smart technologies refer to devices and systems capable of automating processes, making autonomous decisions, and enabling communication between devices through the application of advanced technology (Gubbi et al., 2013). Smart technologies play a crucial role in driving digital transformation and creating added value through data-driven decision-making processes (Porter & Heppelmann, 2014). Systems based on smart technologies also promote collaboration among industry players through automatically connected digital platforms, thereby forming a more integrated and responsive corporate ecosystem (Kagermann et al., 2013). Smart technologies enhance operational efficiency, accelerate the flow of information, and strengthen business resilience amid increasingly complex market dynamics.

Operational Performance

Operational performance encompasses various critical aspects of a company's performance, such as quality, speed, flexibility, cost, and operational reliability (Slack et al., 2010). Enhancing operational performance can be achieved through the application of advanced technologies, effective resource management, and the development of workforce competencies (Kaydos, 1999). Operational performance serves as a primary objective in measuring a company's effectiveness and efficiency in executing its business processes (Neely et al., 1995). In the digital era, companies are required to continuously adopt innovations to maintain competitive and adaptive operational performance in response to changes in the business environment (Chesbrough, 2003).

Hypotheses Development

Instrumented Supply Chain and Operational Performance

The Resource-Based View (RBV) theory by Barney (1991) explains that competitive advantage and efficient company operations heavily depend on the company's ability to utilize valuable, rare, inimitable, and non-substitutable resources. The application of technology and digital devices in an instrumented supply chain plays a crucial role in collecting real-time data from various points in the supply chain. The use of sensor-based hardware and software for collecting, monitoring, and analyzing data is increasingly important to support instrumented supply chains oriented toward process automation. As access to sensor-based innovations becomes more widespread, companies are increasingly encouraged to adopt this technology to improve operational performance (Dolgui & Ivanov, 2022). Bayraktar et al. (2009) emphasized that supply chain integration, including integration with suppliers, is positively correlated with the success and enhancement of a company's operational performance. The instrumented supply chain is a strategic resource because it involves the implementation of digital technologies that support automation and data-driven decision-making. The concept of the instrumented supply chain is an evolution of the smart supply chain model, which has garnered significant attention for its impact on enhancing business and operational performance (Ramakrishna et al., 2023). Based on the aforementioned description, the first hypothesis proposed is:

H1: Instrumented supply chain has a positive influence on operational performance.

Interconnected Supply Chain and Operational Performance

The RBV approach explains that a company's ability to achieve operational excellence depends on the use of strategic assets that are difficult to imitate, including digitally integrated supply chain systems (Barney, 1991). One of these strategic assets is the interconnected supply chain, which is a supply chain that is connected through information and communication technology to enable real-time data exchange. Through this system, companies can build supply chains that are more responsive, cohesive, and adaptive to market changes. Interconnected supply chains support faster and more accurate decision-making, strengthen collaboration between business partners, and minimize delays and errors in operational processes. Ivanov and Keskin (2023) emphasize that digital integration in the supply chain increases the visibility of the flow of goods and information, which contributes to timeliness, cost efficiency, and increased customer satisfaction.

Several previous studies also support the positive relationship between an interconnected supply chain and operational performance. Ben-Daya et al. (2019) show that supply chain digitalization can improve operational effectiveness by reducing lead time and increasing demand accuracy. Furthermore, the integration of information technology in supply chain relationships significantly improves process efficiency and logistics coordination and directly affects operational performance through faster and more responsive decision making (Yu et al., 2018). Dubey et al. (2019) show that digital technology in the supply chain contributes significantly to operational efficiency and data-driven decision making. Ambrogio et al. (2022) show that in the manufacturing sector, digital supply networks help companies maintain operations during the COVID-19 disruption by flexibly adjusting capacity and resources. Based on this description, the second hypothesis proposed is:

H2: Interconnected supply chains have a positive influence on operational performance.

Instrumented Supply Chain and Smart Technology

According to the RBV, long-term competitive advantage is achieved through the utilization of strategic resources that are valuable, rare, inimitable, and difficult to substitute (Barney, 1991). One such resource is the integration of instrumented supply chains and smart technologies. This integration drives companies to build supply chain systems that are intelligent, efficient, and responsive to market changes. An instrumented supply chain refers to a system equipped with digital devices and automation technologies designed to generate, collect, and manage data in real time. Research by Rawat (2022) confirms that applying smart technologies within supply chains can lower transaction costs and enhance efficiency across all supply chain functions. Zhang et al. (2023) highlight that supply chain management systems based on smart technologies enable manufacturing firms to anticipate demand shifts and optimize their production processes. Furthermore, Cahyaningratri and Naylah (2023) emphasize that organizations capable of comprehensively integrating digital technologies will gain maximum benefits from smart technology implementation in terms of productivity and strategic decision-making. Based on this description, the third hypothesis proposed is:

H3: Instrumented supply chains have a positive influence on smart technology.

The Influence of Interconnected Supply Chain on Smart Technology

The development of information technology has driven significant transformation in the supply chain system, especially through the integration of information systems and real-time data flows. One of the key elements in an intelligent supply chain is the interconnected supply chain, which is the overall system connectivity between upstream and downstream of the supply chain, including integration with customers, suppliers, and products moving along the supply chain. This connectivity not only strengthens collaboration between parties but also improves the overall understanding of supply chain dynamics (Lee et al., 2023).

With an interconnected supply chain, companies can interact directly not only with internal systems and external partners but also with products being processed or shipped (Ivanov & Keskin, 2023). This results in increased collaboration, visibility, and adaptive capabilities in modern logistics systems. In addition, smart technology helps companies in collecting and processing large-scale data automatically and accurately (Tiwari et al., 2018). The interconnected supply chain system directly supports the development of smart technology by providing the data infrastructure and connectivity needed for automation, artificial intelligence, and machine learning in production and logistics processes (Verdouw et al., 2016). Furthermore, smart technology offers great potential in integrating software and materials across multiple platforms, infrastructures, and production systems (Cahyaningratri & Naylah, 2023). Based on this description, the fourth hypothesis proposed is:

H4: The interconnected supply chain positively influences smart technology.

The Influence of Smart Technology on Operational Performance

According to Barney (1991), RBV theory, a company's competitiveness is primarily driven by internal resources that are valuable, rare, inimitable, and non-substitutable (VRIN). In this context, the integration and interconnection within a supply chain represent a critical strategic asset that aligns with VRIN attributes. When supply chain components are effectively interconnected through timely processes, robust collaboration among partners, and coordinated logistics and operations, companies can gain substantial strategic and operational advantages.

The adoption of smart supply chain practices has been shown to significantly enhance operational performance by increasing production efficiency and maximizing value across manufacturing infrastructure and systems (Hanaysha & Alzoubi, 2022). Smart technologies facilitate real-time and accurate data acquisition, enabling industries to respond promptly and efficiently to operational challenges and improve overall supply chain performance. Specifically, smart technologies refer to physical entities embedded with digital capabilities known as digital artifacts possessing features such as programmability, addressability, sensitivity, communication, memory, and associability, which allow interactive and insightful functionality for businesses. Moreover, smart technologies not only foster internal integration but also enhance external collaboration by supporting digitalized processes and real-time information exchange throughout the supply chain. For instance, they enable collaborative planning and execution by streamlining workflows through digital connectivity (Rawat et al., 2022). Based on this explanation, the fifth hypothesis proposed is:

H5: Smart technology has a positive influence on operational performance.

The Mediating Role of Smart Technology on the Influence of Instrumented Supply Chain on Operational Performance

From the perspective of the RBV, a company's sustained competitive advantage is primarily shaped by its capacity to leverage strategic resources that are valuable, rare, and difficult to replicate, such as accurate, systematically processed data (Barney, 1991). In this regard, smart technology serves as a key enabler within manufacturing and service-based supply chains by enhancing operational efficiency and strengthening overall competitive positioning. Smart technology facilitates the transformation of raw data collected across various supply chain points into actionable insights for strategic decision-making (Li et al., 2019; Wu et al., 2016). For instance, technologies like RFID have proven more effective than traditional methods in managing logistics and inventory systems.

The synergy between instrumented supply chains and smart technologies enables continuous, real-time monitoring of operations via embedded digital tools. This capability can lead to reduced inventory holding costs and lower risk of stockouts. Additionally, the digital transformation driven by smart technologies supports enhanced customer service and fosters external collaboration by processing vast volumes of data from diverse sources. These developments ultimately contribute to improved operational efficiency and greater supply chain effectiveness (Bienhaus & Haddud, 2018). Based on this reasoning, the sixth hypothesis proposed is:

H6: Smart technology mediates the positive influence of the instrumented supply chain on operational performance.

The Mediating Role of Smart Technology on the Influence of Interconnected Supply Chain on Operational Performance

According to the RBV theory, a company's competitive advantage can be realized when it successfully leverages strategic resources that are valuable, rare, inimitable, and non-substitutable (Barney, 1991). In this context, smart technology plays a pivotal role in reinforcing the relationship between interconnected supply chains and enhanced operational performance. By enabling real-time integration and seamless communication among all stakeholders across the supply chain, both upstream and downstream, smart technology facilitates greater process efficiency, accelerates production activities, and reduces logistics costs (Ramakrishna et al., 2023). Moreover, smart technology enhances connectivity between customers, suppliers, assets, and information systems, thereby improving operational coordination, agility, and responsiveness (Gupta et al.,

2019). Based on this theoretical and empirical foundation, the seventh hypothesis proposed is:

H7: Smart technology mediates the positive influence of an interconnected supply chain on operational performance.

Research Framework Model

Figure 1. Research Framework Model

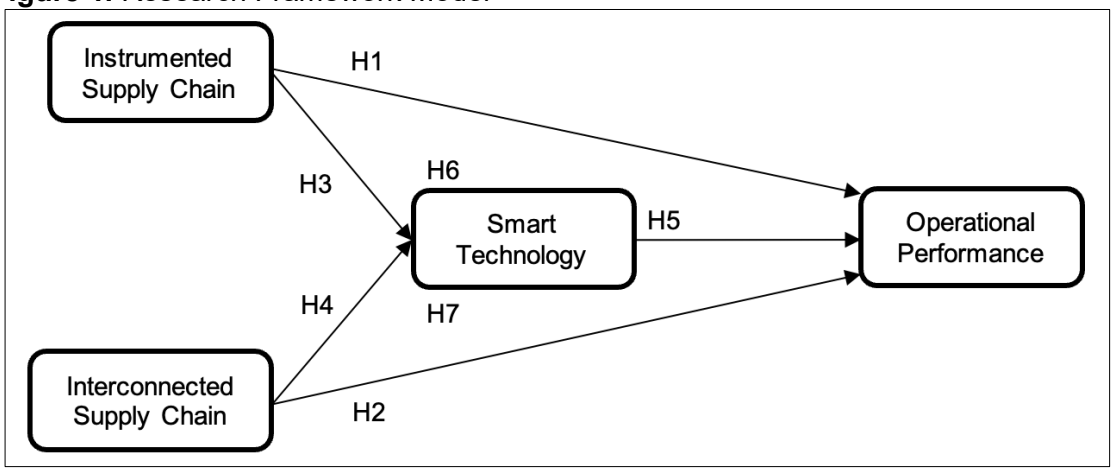


Figure 1 illustrates the conceptual framework of this study, which investigates the influence of the instrumented supply chain and interconnected supply chain on operational performance, with smart technology serving as a mediating variable. The model comprises seven hypothesized relationships. H1 proposes a direct positive effect of the instrumented supply chain on operational performance, while H2 examines the direct effect of the interconnected supply chain on operational performance. H3 and H4 assess the influence of the instrumented supply chain and interconnected supply chain, respectively, on smart technology adoption. H5 tests the effect of smart technology on operational performance. Meanwhile, H6 and H7 explore the mediating role of smart technology in the relationships between the instrumented supply chain and operational performance and between the interconnected supply chain and operational performance.

RESEARCH METHOD

This study employs a quantitative research approach that emphasizes the collection and analysis of numerical data. Quantitative data refers to information expressed in numerical form or transformed into numbers through scoring or rating processes to facilitate statistical analysis. This method is selected to strengthen the examination of relationships between variables and to generate objective, measurable findings (Sugiyono, 2023).

The sample in this research consists of employees working in MSMEs within the manufacturing sector, selected using a purposive sampling technique based on specific criteria: (a) employees with a minimum of one year of work experience in the manufacturing industry; (b) employees possessing a relevant understanding of the studied variables; and (c) employees who have participated in training or seminars related to operational management and smart technology. A total of 100 respondents were included in this study, aligning with the recommended sample size for Structural Equation Modeling (SEM), which ranges between 100 and 300 for robust parameter estimation (Hair et al., 2021). The research instrument used a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) for all indicators.

Data analysis was conducted using Smart PLS software version 4.0. In this analysis, the validity and reliability of the measurement model were assessed through tests of convergent validity, discriminant validity, and composite reliability. According to Ghozali (2021), an individual indicator is considered valid if it has a loading factor greater than 0.70. Construct reliability is determined by composite reliability and Cronbach's alpha, with a variable deemed reliable if it has a composite reliability value ≥ 0.70 and a Cronbach's alpha ≥ 0.60. Hypothesis testing is conducted using the p-value criterion, where a hypothesis is accepted if the p-value is less than 0.05.

This study includes three types of variables: dependent, independent, and mediating variables. The dependent variable is operational performance, measured using six indicators adopted from Lee et al. (2023). The independent variables include the instrumented supply chain with three indicators and the interconnected supply chain with five indicators, both adapted from Lee et al. (2023). The mediating variable, smart technology, is measured using five indicators also adopted from Lee et al. (2023).

RESULTS

Demographic Statistics Respondent Characteristics

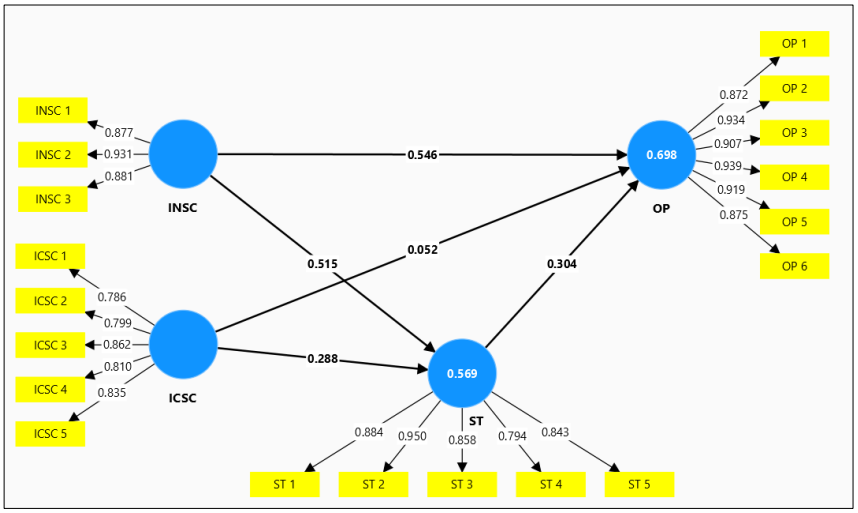
Table 1. Statistics Demographics

Characteristics	Category	Frequency	Percentage
Gender	Man	69	69%
	Woman	31	31%
Age	18- 22 Years	13	13%
	23-27 Years	26	26%
	28-32 Years	27	27%
	33-37 Years	14	14%
	38-42 Years	12	12%
	43-47 Years	3	3%
	48-52 Years	5	5%
Length of Work	1-5 Years	66	66 %
	6-10 Years	24	24%
	11-15 Years	7	7%
	16-20 Years	3	3%
Income	1-5 Million	54	54%
	6-10 Million	46	46%

The results presented in Table 1 indicate that the total sample consisted of 100 respondents, with 69% identifying as male and 31% as female. In terms of age distribution, 13% of respondents were aged 18–22 years, 26% were aged 23–27 years, 27% were aged 28–32 years, 14% were aged 33–37 years, 12% were aged 38–42 years, 3% were aged 43–47 years, and 5% were aged 48–52 years. Regarding work experience, 42% of respondents had been employed for 1–5 years, 10% for 5–10 years, 11% for 10–15 years, and 32% for 15–20 years. In terms of monthly income, the majority (54%) reported earning between 1–5 million IDR, while 2% earned between 6–10 million IDR. All employees in this study have understood the research variables and have attended a seminar on operations management and smart technology.

Measurement of Variables

Figure 2. Results of Variable Measurement



The preliminary analysis involved evaluating the measurement model to confirm the validity of the research instrument, as shown in Figure 2. Validity was assessed by examining the loading values of each indicator. Based on the figure, all indicators across the measured variables are considered valid, as each has an outer loading value exceeding 0.70, in accordance with the threshold suggested by Hair et al. (2021).

Discriminant Reliability Value

Table 2. Discriminant Reliability Results

	Cronbach's Alpha (CA)	Composite Reliability (CR)	Average Variance Extracted (AVE)
ICSC	0.877	0.881	0.670
INSC	0.878	0.884	0.804
OP	0.957	0.958	0.824
ST	0.917	0.921	0.752

Note: ICSC (Interconnected Supply Chain), INSC (Instrumented Supply Chain), OP (Operational Performance), ST (Smart Technology)

According to the reliability test results presented in Table 2, the ICSC variable shows a Cronbach's Alpha of 0.877, a Composite Reliability of 0.881, and an AVE of 0.670. The INSC variable records a Cronbach's Alpha of 0.878, a Composite Reliability of 0.884, and an AVE of 0.804. The OP variable achieves a Cronbach's Alpha of 0.957, a Composite Reliability of 0.958, and an AVE of 0.824. Meanwhile, the ST variable has a Cronbach's Alpha of 0.917, a Composite Reliability of 0.921, and an AVE of 0.752.

R-Square Value

Table 3. R-Square Value Results

	R-Square	R-square adjusted
OP	0.698	0.689
ST	0.569	0.560

Note: ICSC (Interconnected Supply Chain), INSC (Instrumented Supply Chain), OP (Operational Performance), ST (Smart Technology)

Based on the analysis results presented in Table 3, the R-Square value for the Operational Performance variable is 0.698, with an adjusted R-Square of 0.689. This indicates that 69.8% of the variation in operational performance can be explained by the independent variables included in the model. Meanwhile, for the Smart Technology

variable, the R-Square value is 0.569 and the adjusted R-Square is 0.560, showing that 56.9% of the variation in Smart Technology is accounted for by the variables incorporated into the model.

Fornell-Larcker Criterion Value

Table 4. Results of the Fornell-Larcker Criterion Values

	ICSC	INSC	OP	ST
ICSC	0.819			
INSC	0.749	0.897		
OP	0.665	0.806	0.908	
ST	0.673	0.730	0.737	0.867

Note: ICSC (Interconnected Supply Chain), INSC (Instrumented Supply Chain), OP (Operational Performance), ST (Smart Technology)

The Fornell-Larcker Criterion assesses discriminant validity by comparing the square root of the Average Variance Extracted (AVE) for each construct with its correlations to other constructs (Fornell & Larcker, 1981). As shown in the analysis results in Table 4, the AVE root value for ICSC is 0.819, for INSC is 0.897, for OP is 0.908, and for ST is 0.867. These findings demonstrate that all constructs in the model exhibit strong discriminant validity, as the square root of each construct's AVE exceeds its correlation with other constructs. This confirms that every construct captures a distinct and specific dimension within the research mode.

Direct and Indirect Test Results

Table 5. Results of Direct Testing and Indirect Testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistic (IO/STDEVI)	P Values	Description
INSC -> OP	0.546	0.544	0.120	4.532	0.000	Accepted
ICSC -> OP	0.052	0.055	0.105	0.493	0.622	Rejected
INSC -> ST	0.515	0.509	0.120	4.292	0.000	Accepted
ICSC -> ST	0.288	0.296	0.114	2.531	0.011	Accepted
ST -> OP	0.304	0.304	0.123	2.462	0.014	Accepted
INSC -> ST -> OP	0.156	0.157	0.078	0.998	0.046	Accepted
ICSC -> ST -> OP	0.087	0.088	0.048	1.804	0.071	Rejected

Note: ICSC (Interconnected Supply Chain), INSC (Instrumented Supply Chain), OP (Operational Performance), ST (Smart Technology)

The results presented in Table 5 demonstrate several significant relationships among the research variables. The instrumented supply chain (INSC) has a positive and significant direct effect on operational performance (OP) with a path coefficient of 0.546 and a p-value of 0.000, indicating a strong impact (H1 accepted). In contrast, the interconnected supply chain (ICSC) shows no significant direct effect on operational performance, as reflected by the low coefficient of 0.052 and a p-value of 0.622 (H2 rejected). Regarding the effect on smart technology (ST), both INSC and ICSC exhibit significant positive influences, with coefficients of 0.515 ($p = 0.000$) and 0.288 ($p = 0.011$), supporting H3 and H4, respectively. Moreover, smart technology itself significantly contributes to improving operational performance ($\beta = 0.304$; $p = 0.014$), thus H5 is accepted.

From the perspective of mediation analysis, smart technology is found to mediate the relationship between the instrumented supply chain and operational performance, as

indicated by a significant indirect effect (β = 0.156; p = 0.046), which confirms H6. However, smart technology does not mediate the relationship between the interconnected supply chain and operational performance, with a p-value of 0.071, exceeding the conventional threshold of 0.05, resulting in the rejection of H7. These findings underscore the critical role of smart technology in enhancing the benefits of digital instrumentation in supply chains, while also suggesting that connectivity alone may not be sufficient to improve performance without other supporting conditions.

DISCUSSION

The Influence of Instrumented Supply Chain on Operational Performance

The analysis presented in Table 5 indicates that the instrumented supply chain exerts a significant positive influence on operational performance, with a p-value of 0.000. These findings demonstrate that the implementation of an instrumented supply chain makes a substantial contribution to enhancing operational efficiency, particularly in inventory management, quality control, and real-time production monitoring. According to the RBV theory, the instrumented supply chain qualifies as a strategic, technology-driven resource that is valuable, rare, difficult to imitate, and irreplaceable, thus providing a basis for achieving sustainable competitive advantage (Barney, 1991; Wernerfelt, 1984). This technology enhances the internal capabilities of a company in adapting swiftly and effectively to both operational and market changes, leading to improved overall performance (Teece et al., 1997).

These results are consistent with the study by Lee et al. (2023), which highlights how technology integration in instrumented supply chains improves visibility, logistics efficiency, and supports data-driven decision making. Similarly, Chau et al. (2021) found that the use of automated monitoring and real-time data collection can boost process efficiency and enable more precise planning, especially in the manufacturing sector.

The Influence of Interconnected Supply Chain on Operational Performance

The analysis reveals that the interconnected supply chains do not have a positive impact on operational performance, as evidenced by a p-value of 0.622. These findings align with the study by Dolgui and Ivanov (2022), which suggests that an interconnected supply chain does not directly influence operational performance but requires the presence of mediating variables such as smart technology. Similarly, He et al. (2020) found that although interconnected supply chain systems can potentially enhance responsiveness and operational efficiency, their effectiveness is highly dependent on other factors, including technological preparedness and communication among supply chain partners.

This result can be understood through the lens of contingency theory, which asserts that no single strategy or management system is universally effective; instead, its success hinges on the alignment between applied practices and the organizational environment (Donaldson, 2001). Therefore, the implementation of an interconnected supply chain will not automatically lead to better operational performance unless supported by contingency elements like technological infrastructure, coordination capacity, and adaptive organizational systems. In essence, if the technology employed is not well-suited to the organization's conditions, the benefits of an interconnected supply chain cannot be fully realized (Lawrence & Lorsch, 1967).

The Influence of Instrumented Supply Chain on Smart Technology

The analysis shows that the instrumented supply chain positively influences smart technology, as indicated by a P-value of 0.000. This result suggests that greater adoption of the instrumented supply chain leads to increased utilization of smart technology within

supply chain systems. According to RBV theory, both instrumented supply chains and smart technology are strategic, technology-based assets that are valuable, rare, difficult to imitate, and irreplaceable (Barney, 1991). The ability of a company to integrate these complementary systems enhances internal capabilities and establishes long-term competitive advantages in supply chain operations (Teece et al., 1997; Wernerfelt, 1984). This is made possible by the integration of advanced hardware and software that facilitate real-time data collection and analysis.

Such integration directly supports the deployment of smart technology to enhance the efficiency and effectiveness of operational activities (Lee et al., 2023). Ramakrishna et al. (2023) highlight that the synergy between smart technology and instrumented supply chain systems enhances data-driven decision-making and accelerates responses to market fluctuations. Similarly, Dai et al. (2022) assert that digitalization enabled by instrumented supply chains forms a crucial foundation for building a responsive and efficient smart supply chain.

The Influence of Interconnected Supply Chain on Smart Technology

The analysis results indicate that the interconnected supply chain has a positive effect on smart technology, as shown by a P-value of 0.011. The connectivity among information systems, business partners, and digital tools promotes the integration of cloud-based platforms and big data solutions. AlMulhim (2021) noted that companies with highly connected supply chains are more likely to invest in smart technology to enhance collaboration and better respond to shifting market demands. This suggests that the more integrated the system and information flow within the supply chain, the higher the likelihood of effective smart technology adoption.

These findings align with the study by Cahyaningratri and Naylah (2023), which confirmed that interconnected supply chains support smart technology implementation. Similarly, Dolgui and Ivanov (2022) found a significant long-term positive impact of interconnected supply chains on smart technology use. Chau et al. (2021) also reinforced this conclusion by showing that strong connectivity among supply chain entities enables the effective application of advanced technologies like smart technology.

The Influence of Smart Technology on Operational Performance

The analysis shows that smart technology has a positive effect on operational performance, as indicated by a P-value of 0.014. This finding is consistent with the research of Shao et al. (2021), which demonstrates that smart technology can directly influence operational performance. Similarly, the study by Sukathong et al. (2021) confirms that smart technology has a significant and direct positive effect on operational outcomes. These results highlight that the success of smart technology implementation is closely tied to contextual factors within the company, such as infrastructure readiness, effective system integration, and a supportive organizational culture. This relationship can be further explained through the lens of the RBV, which emphasizes that sustainable competitive advantage stems from the strategic use of resources that are valuable, rare, inimitable, and non-substitutable (Barney, 1991).

Smart technology qualifies as such a strategic resource, as it enhances a company's internal capabilities, particularly in managing complex operations and adapting to rapidly changing market conditions. However, the realization of its full potential depends on the presence of complementary enablers, including robust infrastructure, integrated systems, and a culture that supports technological adaptation conditions that empower organizations to maximize the strategic value of smart technology (Teece et al., 1997; Wernerfelt, 1984).

The Mediating Role of Smart Technology on the Influence of Instrumented Supply Chain on Operational Performance

The analysis shows that smart technology mediates the influence of the instrumented supply chain on operational performance, with a P-value of 0.046. This finding suggests that the positive effect of the instrumented supply chain on operational performance becomes more pronounced when facilitated by the application of smart technology. This study aligns with the findings of Naway and Rahmat (2019), who assert that smart technology plays a critical mediating role by enhancing efficiency and effectiveness within the operational processes of the supply chain.

Moreover, Rawat (2022) emphasizes that the success of smart technology in its mediating role heavily depends on the quality of interactions and the credibility of information exchanged among supply chain actors. These insights reinforce the idea that the integration of smart devices and automated systems within smart technology accelerates real-time data collection and processing, thereby enabling faster, more accurate decision-making. This acceleration contributes directly to the enhancement of overall operational performance. Additionally, this result is supported by Li (2020), whose research illustrates that the optimization of the instrumented supply chain through smart technology adoption can lead to substantial reductions in operational costs and a notable increase in efficiency across the entire supply chain system.

The Mediating Role of Smart Technology on the Influence of Interconnected Supply Chain on Operational Performance

The analysis results reveal that smart technology does not mediate the effect of the interconnected supply chain on operational performance, as indicated by a P-value of 0.071. Although there is a relationship between the interconnected supply chain and operational performance, smart technology does not statistically provide a sufficiently strong bridge to enhance or reinforce this influence. This finding supports the study by Lee et al. (2023), which explains that while smart technology may have the potential to mediate the relationship between an interconnected supply chain and operational performance, its effectiveness as a mediator is not always significant and depends greatly on the specific application context. Similarly, Chung et al. (2022) highlight that the efficacy of smart technology in strengthening this link is largely influenced by organizational and industry characteristics. In some cases, particularly in organizations with underdeveloped digital infrastructure or low levels of technological readiness, smart technology is less effective in amplifying the impact of an interconnected supply chain on operational performance.

This result can be better interpreted through the lens of contingency theory, which asserts that no single organizational strategy or technological solution is universally effective. Instead, successful outcomes depend on the degree of fit between internal systems and the external environment (Donaldson, 2001). The limited role of smart technology as a mediator suggests a misalignment between the digital tools implemented and the firm's specific conditions, such as operational context, IT capacity, and preparedness for digital transformation. Hence, for smart technology to deliver significant operational improvements, its adoption must be strategically aligned with the unique needs and situational factors of the organization (Lawrence & Lorsch, 1967).

CONCLUSION

This study aims to analyze the influence of instrumented supply chain and interconnected supply chain on operational performance, with smart technology as a mediating variable, in the context of manufacturing MSMEs in Yogyakarta. Based on the analysis results, it can be concluded that the instrumented supply chain has a significant

positive effect on operational performance. Meanwhile, the interconnected supply chain does not have a significant direct effect on operational performance. Both the instrumented supply chain and the interconnected supply chain significantly influence the adoption of smart technology. In turn, smart technology has a significant positive impact on operational performance. Furthermore, smart technology is proven to mediate the positive influence of the instrumented supply chain on operational performance. However, smart technology does not mediate the relationship between the interconnected supply chain and operational performance. These findings highlight the importance of digital instrumentation in supply chains and the pivotal role of smart technology in improving performance outcomes for manufacturing MSMEs.

Suggestions for future research include exploring additional mediating or moderating variables, such as organizational readiness, digital literacy, or environmental uncertainty, that may affect the relationship between supply chain digitalization and operational outcomes. Further studies should also consider different industrial sectors or geographic contexts to increase the generalizability of findings. Theoretical implications of this study contribute to the development of digital supply chain literature by emphasizing the importance of smart technology as a mediating factor. Practically, this research provides insights for MSME actors and policymakers to prioritize the development of instrumented supply chains and invest in smart technologies to enhance efficiency, responsiveness, and competitiveness in the Industry 4.0 era.

LIMITATION

This study has several limitations, including: First, this study focuses more on the relationship between the variables interconnected supply chain, instrumented supply chain, and smart technology to operational performance. For further research, studies on other external factors that affect operational performance need to be conducted, such as government policies, global market conditions, or macroeconomic variables. Second, this study uses a quantitative approach that relies on survey data, which may not fully reflect the dynamics that occur in the field, so there is a bias in respondents or limitations in measuring the variables used.

ACKNOWLEDGMENT

The author would like to thank all respondents and organizations who have been willing to provide data and information needed in this study. Thankfulness is also conveyed to the academic supervisor and reviewers who have provided constructive input in the process of compiling and refining this article.

DECLARATION OF CONFLICTING INTERESTS

Practically, the results of this study provide implications that strengthening the instrumented supply chain and utilizing smart technology need to be a priority in efforts to improve operational efficiency. Theoretically, these findings contribute to the development of the literature by emphasizing the mediating role of smart technology in the relationship between supply chain digitalization and operational performance.

REFERENCES

AlMulhim, A. F. (2021). Smart supply chain and firm performance: the role of digital technologies. *Business Process Management Journal*, *27*(5), 1353-1372. https://doi.org/10.1108/BPMJ-12-2020-0573

Alshurideh, M. T., Alquqa, E. K., Alzoubi, H. M., Al Kurdi, B., & Alhamad, A. (2023a). The impact of cyber resilience and robustness on supply chain performance: Evidence from the UAE chemical industry. *Uncertain Supply Chain Management*, *11*(1), 187-194. https://doi.org/10.5267/j.uscm.2022.10.008

Alshurideh, M. T., Alquqa, E. K., Alzoubi, H. M., Al Kurdi, B., & Hamadneh, S. (2023b). 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

Alzoubi, H. M., Elrehail, H., Hanaysha, J. R., Al-Gasaymeh, A., & Al-Adaileh, R. (2022). The role of supply chain integration and agile practices in improving lead time during the COVID-19 crisis. *International Journal of Service Science, Management, Engineering, and Technology*, *13*(1), 1-11. https://doi.org/10.4018/IJSSMET.290348

Ambrogio, G., Filice, L., Longo, F., & Padovano, A. (2022). Workforce and supply chain disruption as a digital and technological innovation opportunity for resilient manufacturing systems in the COVID-19 pandemic. *Computers & Industrial Engineering*, *169*, 108158. https://doi.org/10.1016/j.cie.2022.108158

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99-120. https://doi.org/10.1177/014920639101700108

Bayraktar, E., Demirbag, M., Koh, S. L., Tatoglu, E., & Zaim, H. (2009). A causal analysis of the impact of information systems and supply chain management practices on operational performance: Evidence from manufacturing SMEs in Turkey. *International Journal of Production Economics*, *122*(1), 133-149. https://doi.org/10.1016/j.ijpe.2009.05.011

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: A literature review. *International Journal of Production Research*, *57*(15-16), 4719-4742. https://doi.org/10.1080/00207543.2017.1402140

Bienhaus, F., & Haddud, A. (2018). Procurement 4.0: factors influencing the digitisation of procurement and supply chains. *Business Process Management Journal*, *24*(4), 965-984. https://doi.org/10.1108/BPMJ-06-2017-0139

Butner, K. (2010). The smarter supply chain of the future. *Strategy & Leadership*, *38*(1), 22-31. https://doi.org/10.1108/10878571011009859

Cahyaningratri, C., & Naylah, M. (2023). The effect of supply chain operational capabilities in consolidating organizational compatibility of supply chain process integration and business performance. *Uncertain Supply Chain Management*, *11*(1), 95-102. https://doi.org/10.5267/j.uscm.2022.11.006

Central Agency of Statistics of DI Yogyakarta Province (BPS Provinsi DIY). (2024, May 6). *Pertumbuhan Ekonomi DIY Triwulan I 2024*. BPS DI Yogyakarta. https://yogyakarta.bps.go.id/id/pressrelease/2024/05/06/1596/pertumbuhan-ekonomi-diy-triwulan-i-2024.html

Chau, K. Y., Tang, Y. M., Liu, X., Ip, Y. K., & Tao, Y. (2021). Investigation of critical success factors for improving supply chain quality management in manufacturing. *Enterprise Information Systems*, *15*(10), 1418-1437. https://doi.org/10.1080/17517575.2021.1880642

Chesbrough, H. W. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business Press.

Chung, J. E., Oh, S. G., & Moon, H. C. (2022). What drives SMEs to adopt smart technologies in Korea? Focusing on technological factors. *Technology in Society*, *71*, 102109. https://doi.org/10.1016/j.techsoc.2022.102109

Dai, Y., Dou, L., Song, H., Zhou, L., & Li, H. (2022). Two-way information sharing of uncertain demand forecasts in a dual-channel supply chain. *Computers & Industrial Engineering*, *169*, 108162. https://doi.org/10.1016/j.cie.2022.108162

Dolgui, A., & Ivanov, D. (2022). 5G in digital supply chain and operations management: fostering flexibility, end-to-end connectivity and real-time visibility through internet-of-everything. *International Journal of Production Research*, *60*(2), 442-451. https://doi.org/10.1080/00207543.2021.2002969

Donaldson, L. (2001). *The Contingency Theory of Organizations*. Sage Publications.

Dubey, R., Gunasekaran, A., Childe, S. J., Blome, C., & Papadopoulos, T. (2019). Big data and predictive analytics and manufacturing performance: integrating institutional theory, resource-based view and big data culture. *British Journal of Management*, *30*(2), 341-361. https://doi.org/10.1111/1467-8551.12355

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39-50. https://doi.org/10.1177/002224378101800104

Ghozali, I. (2021). *Partial Least Squares (PLS) Metode Alternatif Structural Equation Modeling (SEM)* (7th ed.). Badan Penerbit Universitas Diponegoro.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, *29*(7), 1645-1660. https://doi.org/10.1016/j.future.2013.01.010

Guo, X., Zhang, G., & Zhang, Y. (2022). A comprehensive review of blockchain technology-enabled smart manufacturing: A framework, challenges and future research directions. *Sensors*, *23*(1), 155. https://doi.org/10.3390/s23010155

Gupta, S., Drave, V. A., Bag, S., & Luo, Z. (2019). Leveraging smart supply chain and information system agility for supply chain flexibility. *Information Systems Frontiers*, *21*(3), 547-564. https://doi.org/10.1007/s10796-019-09901-5

Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). *Partial least squares structural equation modeling (PLS-SEM) using R: A Workbook*. Springer Nature.

Hanaysha, J. R., & Alzoubi, H. M. (2022). The effect of digital supply chain on organizational performance: An empirical study in Malaysia manufacturing industry. *Uncertain Supply Chain Management*, *10*(2), 495-510.

He, L., Xue, M., & Gu, B. (2020). Internet-of-things enabled supply chain planning and coordination with big data services: Certain theoretic implications. *Journal of Management Science and Engineering*, *5*(1), 1-22. https://doi.org/10.1016/j.jmse.2020.03.002

Ivanov, D., & Keskin, B. B. (2023). Post-pandemic adaptation and development of supply chain viability theory. *Omega*, *116*, 102806. https://doi.org/10.1016/j.omega.2022.102806

Ivanov, D., Das, A., & Choi, T. M. (2018). New flexibility drivers for manufacturing, supply chain and service operations. *International Journal of Production Research*, *56*(10), 3359-3368. https://doi.org/10.1080/00207543.2018.1457813

Jaekel, B. (2020, June 26). *A Smart Supply Chain Is an Efficient One*. Supply & Demand Chain Executive. https://www.sdcexec.com/software-technology/software-solutions/article/21133671/a-smart-supply-chain-is-an-efficient-one

Kache, F., & Seuring, S. (2017). Challenges and opportunities of digital information at the intersection of big data analytics and supply chain management. *International Journal of Operations & Production Management*, *37*(1), 10-36. https://doi.org/10.1108/IJOPM-02-2015-0078

Kagermann, H., Wahlster, W., & Helbig, J. (2013). *Recommendations for Implementing the Strategic Initiative Industrie 4.0: Final Report of the Industry 4.0 Working Group*. Acatech – National Academy of Science and Engineering. https://www.din.de/resource/blob/76902/e8cac883f42bf28536e7e8165993f1fd/recommendations-for-implementing-industry-4-0-data.pdf

Kaydos, W. (1999). *Operational Performance Measurement: Increasing Total Productivity*. CRC Press.

Kukanja, M., & Planinc, T. (2020). Toward cost-effective service excellence: Exploring the relationship between managers' perceptions of quality and the operational efficiency and profitability of restaurants. *Quality Management Journal*, *27*(2), 95-105. https://doi.org/10.1080/10686967.2020.1722046

Lawrence, P. R., & Lorsch, J. W. (1967). *Organization and Environment: Managing Differentiation and Integration*. Harvard Business School Press.

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*, 18479790231200614. https://doi.org/10.1177/18479790231200614

Li, G., Tan, J., & Chaudhry, S. S. (2019). Industry 4.0 and big data innovations. *Enterprise Information Systems*, *13*(2), 145-147. https://doi.org/10.1080/17517575.2018.1554190

Li, X. (2020). Reducing channel costs by investing in smart supply chain technologies. *Transportation Research Part E: Logistics and Transportation Review*, *137*, 101927. https://doi.org/10.1016/j.tre.2020.101927

Mehmood, T. (2021). Does information technology competencies and fleet management practices lead to effective service delivery? Empirical evidence from e-commerce industry. *International Journal of Technology Innovation and Management*, *1*(2), 14-41. https://doi.org/10.54489/ijtim.v1i2.26

Naway, F. A., & Rahmat, A. (2019). The mediating role of technology and logistics integration in the relationship between supply chain capability and supply chain operational performance. *Uncertain Supply Chain Management, 7*(3), 553–566. https://doi.org/10.5267/j.uscm.2018.11.001

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. *International Journal of Operations & Production Management*, *15*(4), 80-116. https://doi.org/10.1108/01443579510083622

Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. *Harvard Business Review*, *92*(11), 64-88.

Ramakrishna, Y., Alzoubi, H. M., & Indiran, L. (2023). An empirical investigation of effect of sustainable and smart supply practices on improving the supply chain organizational performance in SMEs in India. *Uncertain Supply Chain Management*, *11*(3), 991-1000. http://doi.org/10.5267/j.uscm.2023.5.001

Rawat, R. (2022). A systematic review of blockchain technology use in e-supply chain in internet of medical things (IoMT). *International Journal of Computations, Information and Manufacturing*, *2*(2). https://doi.org/10.54489/ijcim.v2i2.119

Shao, X. F., Liu, W., Li, Y., Chaudhry, H. R., & Yue, X. G. (2021). Multistage implementation framework for smart supply chain management under industry 4.0. *Technological Forecasting and Social Change*, *162*, 120354. https://doi.org/10.1016/j.techfore.2020.120354

Slack, N., Chambers, S., & Johnston, R. (2010). *Operations Management* (6th ed.). Pearson Education Limited.

Sugiyono, S. (2023). *Metode Penelitian Kuantitatif, Kualitatif dan R&D* (26th ed.). Alfabeta.

Sukathong, S., Suksawang, P., & Naenna, T. (2021). Analyzing the importance of critical success factors for the adoption of advanced manufacturing technologies. *International Journal of Engineering Business Management*, *13*, 18479790211055057. https://doi.org/10.1177/18479790211055057

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509-533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7%3C509::AID-SMJ882%3E3.0.CO;2-Z

Tiwari, S., Wee, H. M., & Daryanto, Y. (2018). Big data analytics in supply chain management between 2010 and 2016: Insights to industries. *Computers & Industrial Engineering*, *115*, 319-330. https://doi.org/10.1016/j.cie.2017.11.017

Verdouw, C. N., Wolfert, J., Beulens, A. J. M., & Rialland, A. (2016). Virtualization of food supply chains with the internet of things. *Journal of Food Engineering*, *176*, 128-136. https://doi.org/10.1016/j.jfoodeng.2015.11.009

Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal*, *5*(2), 171-180. https://doi.org/10.1002/smj.4250050207

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

Yu, W., Chavez, R., Jacobs, M. A., & Feng, M. (2018). Data-driven supply chain capabilities and performance: A resource-based view. *Transportation Research Part E: Logistics and Transportation Review*, *114*, 371-385. https://doi.org/10.1016/j.tre.2017.04.002

Zhang, G., Yang, Y., & Yang, G. (2023). Smart supply chain management in Industry 4.0: The review, research agenda and strategies in North America. *Annals of Operations Research*, *322*(2), 1075-1117. https://doi.org/10.1007/s10479-022-04689-1

ABOUT THE AUTHOR(S)

1st Author
Zilnia Putri is a student at Universitas Ahmad Dahlan in the Department of Management, Faculty of Economics and Business, with a research focus in the field of operations management. She is currently striving to complete her studies to obtain a bachelor's degree at Universitas Ahmad Dahlan.
Email: putrizilnia@gmail.com.

2nd Author
Muhammad Ali Fikri is a lecturer at Universitas Ahmad Dahlan in the Department of Management, Faculty of Economics and Business, with a research focus in the field of operations management, in accordance with the education he has undertaken for his bachelor's and master's degrees at Universitas Gadjah Mada.
Email: muhammad.fikri@mgm.uad.ac.id
ORCID ID: https://orcid.org/0009-0003-8870-655X