

Transforming Operations Management: How Smart Supply Chain and Smart Technologies Transform Operations Management Differently in Manufacturing and Service Industries

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ABSTRACT

The rapid diffusion of smart technologies is transforming supply chain and operations management; however, their effects may differ between manufacturing and service environments. This study examines how instrumented supply chain, effective supplier management, and intelligent supply chain influence operations management through smart technologies, while specifically comparing manufacturing and service organizations. Using a quantitative cross-sectional design, data were collected from 206 respondents, equally representing manufacturing and service organizations. The proposed relationships were assessed using partial least squares structural equation modeling and multi-group analysis. The findings indicate that intelligent supply chain and effective supplier management are important drivers of smart technology utilization, while smart technologies substantially strengthen operations management. The mediation results further demonstrate that smart technologies provide an important pathway through which supply chain capabilities contribute to operational outcomes. Most importantly, the comparative analysis reveals significant differences between manufacturing and service organizations across several structural and indirect relationships, with stronger effects observed in service organizations. The study highlights the importance of industry context when developing smart supply chain strategies and transforming operations management.

Keywords: Smart supply chain, smart technologies, operations management, intelligent supply chain, supplier management, manufacturing industry, service industry.

INTRODUCTION

The rapid integration of digital technologies is reshaping how firms design, coordinate, and execute their operations (Schiavone & Sprenger, 2017; Wang et al., 2026). Technologies such as connected devices, real-time information systems, radio-frequency identification, automated communication, and intelligent data-processing systems increasingly enable organizations to move beyond conventional supply chain practices. Technology leads the companies toward more responsive and technology-enabled operations (Aljumah et al., 2026; Nwabekee et al., 2025). A smart supply chain combines the technological capabilities with the processes of the supply chain to enhance information availability, coordination, responsiveness, and decision making (Nishad et al., 2025). At the same time, operations management becomes more reliant on the organization ability to convert information that is available digitally into timely

operational actions. Studies have shown that the deployment of technology and strategic alignment can lead to better organizational performance (Croteau & Bergeron, 2001; Kearns & Sabherwal, 2006), likewise, the use of supply chain management practices can boost operational performance. However, the implications of smart supply chain capabilities along with the operations could vary depending on industry.

This distinction is critical when considering differences between manufacturing and service organizations in the automotive industry, as this is a relevant industry for highlighting differences in operation enabled by technology. Automotive industry has a highly instrumented manufacturing process and a vast service component, such as vehicle maintenance, repair, diagnostics, spare-parts management, dealerships, and after-sales service (Adeleke et al., 2025). This means manufacturing and service organizations have different operational needs and are part of interdependent ecosystems (Adusei & Tweneboah-Koduah, 2019). Automotive manufacturers tend to focus on coordinating physical materials, production processes, suppliers, inventories, quality control, and product flows (Turnbull et al., 1992). While automotive service organizations emphasize their customer responsiveness, service coordination, diagnostic information, parts availability, and quick problem resolution (Titu & Pop, 2025). The same smart supply chain and smart technology can create different operational value in manufacturing versus service operations.

In this regard, three aspects of smart supply chain development are important: instrumented supply chains, effective supplier management and intelligent supply chains. The process of continuous updating of technological systems and the integration of technologies in the execution of supply chain activities are key points of an instrumented supply chain (Lee et al., 2023). Good supplier management is about supplier selection, quality, long-term supplier relationships, specifications and supplier capability assessment (Eon-Kyung et al., 2001). Intelligent supply chains add these capabilities, through the use of smart processes (Shen & Lin, 2026), monitoring systems and information systems, which facilitates more accurate decision-making. These are important attributes for the automotive industry, as the system continuity relies on the ability to coordinate and link suppliers, manufacturers, distributors, dealers and service providers.

However, technology does not mean better operations management (Mithas et al., 2022). Smart technologies can act as a means of turning supply chain capabilities into operational improvements (Lee et al., 2023). Newly emerging technologies like connected and identifiable devices, environmentally responsive technologies, communication enabled devices and standardized communication protocols can improve the availability and exchange of operational information. In the context of the present study, smart technologies are seen as an intervening mechanism between smart supply chain dimensions and operations management. This view aligns with the general premise that technology and organizational capabilities need to be connected and not used separately (Croteau & Bergeron, 2001).

Therefore, this study aims to explore the effect of smart supply chain capabilities on operations management with smart technologies considering manufacturing and service organizations in automotive industry. The manufacturing and service operations in the same industry context offers a more useful foundation for comparing the operational benefits that can be realized from digital supply chain capabilities across organizational settings. Therefore, the study adds to the

growing body of literature related to smart operations by focusing on operations, but on how and to what extent this is different for manufacturing vs services.

LITERATURE REVIEW

Manufacturing and Service Perspectives on Smart Operations

Technology-based supply chains are a growing reality in manufacturing and service businesses (Jiang et al., 2024), but the potential for smart supply chain integration, and the implications of smart supply chain integration, can vary significantly between the two scenarios. Most manufacturing companies rely on integrated material flows, supplier systems, production lines, inventory control and technology-enabled tracking for smooth operations (Oly Ndubisi et al., 2005). However, service firms are more dependent on information flows, supplier coordination, response to customers, availability of services, and speed of decision making. These distinctions indicate that smart technologies might not provide the same operational value in manufacturing and service, and the differences could result in a failure to replicate the concept in a service setting. The division is especially significant in the automotive sector, where manufacturing is more about the handling and transformation of physical parts (Wang et al., 2024). While automotive services are more focused on diagnostics, maintenance, coordination of spare parts, customer engagement and after-sales services (Balinado et al., 2021). As a result, supplier management and intelligent supply chain capabilities can be different in these settings as they have different operational needs and information reliance. While the role of technological deployment, supply chain practices and strategic alignment in organizational performance has been acknowledged by existing research (Truong et al., 2017). There is limited research on whether these relationships are systematic and different between manufacturing and service organizations. This comparison serves as an important basis for considering smart technologies as a linkage between the capabilities of the supply chain and operations management.

CONCEPTUAL FRAMEWORK

This study follows the Dynamic Capabilities View (DCV) (Arend & Bromiley, 2009), which defines the role of the resources and capabilities of the organizations in their development, integration, and reconfigure in order to adapt to new conditions in their operation. From this point of view, smart supply chain capabilities can be defined as capabilities of an organization that allow them to sense the requirements of operations (Lee et al., 2023), coordinate the supply chain resources, and react to the changing market and technological conditions. The framework contains three dimensions of smart supply chain capability: instrumented supply chain, effective supplier management, and intelligent supply chain. These capabilities help in smart technology adoption and effective use (Sharma et al., 2023), and in turn, improve the management of operations. Smart technologies are a tool for converting supply chain capabilities into better supply chain outcomes. Moreover, as suggested in DCV, the framework suggests that these relationships can be different depending on organizational context. Therefore, the manufacturing and service firms within the automotive industry are compared to identify the difference in their contribution to operations management that smart supply chain capabilities and technologies make in the two settings. Finally, based on DCV, the current study provided framework of the study in Figure 1.

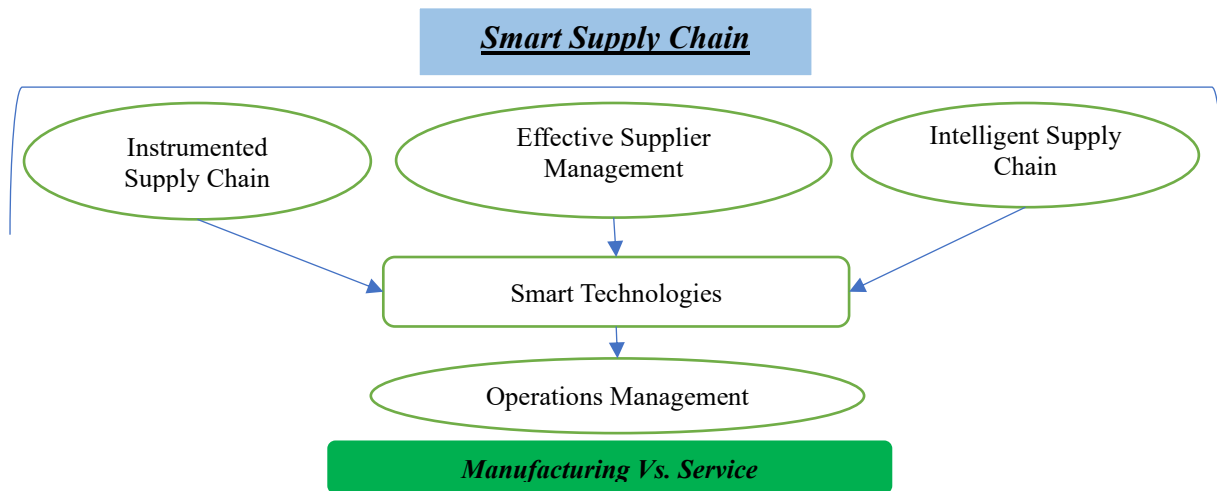


Figure 1: Framework of the study showing the relationship between smart supply chain, smart technologies and operational management among manufacturing vs. service industries

Hypotheses Development

Smart Supply Chain and Smart Technologies

An instrumented supply chain applies digital technologies to the activities of the supply chain and allows companies to gather, share and leverage information about operations more effectively (Gupta et al., 2019; Lee et al., 2023). In the automotive sector, such instrumentation can help in real-time coordination of production, inventory, logistics and supplier activities (Zhao & Ding, 2024). The embedding of technologies and frequent system updates results in an infrastructure that enables the uptake and use of smart technologies more effectively. Technological deployment is an important organizational capability that transforms technological resources into organizational outcomes. Likewise, supplier management that involves supplier quality, supplier capability assessment, clear specifications and long-term relationships gives the organizational base required to put in place the technology-enabled supply chain processes. Coordination with suppliers can be enhanced to enhance information sharing and integrate digital technology across organizational settings (Truong et al., 2017). Consequently, companies with more robust supply chains, and more effective supplier management, should implement smart technologies.

An intelligent supply chain is an extension of the conventional supply chain using smart processes (Alii et al., 2025), monitoring devices, and information systems to aid in the accurate and timely decision making. Intelligent supply chain practices can support the planning, sourcing, delivery, monitoring and coordination of manufacturing and service functions in the automotive industry (Teixeira et al., 2025). These functions enhance the information available and its quality for smart technological applications. Technological capabilities are more valuable when inserted into the organizational processes and strategic activities (Hao & Song, 2016). Intelligent supply chain capabilities can also be defined as dynamic capability mechanisms that enable the firm to combine and reconfigure resources in response to evolving operational needs. Therefore, companies with intelligent supply chain capabilities are more likely to use and implement smart technologies successfully. Therefore, the following hypotheses are proposed:

H1: The integration of an instrumented supply chain is expected to strengthen the adoption and utilization of smart technologies.

H2: The integration of an effective supplier management is expected to strengthen the adoption and utilization of smart technologies.

H3: The integration of an intelligent supply chain is expected to strengthen the adoption and utilization of smart technologies.

Smart Technologies and Operations Management

Smart technologies can enhance operations management by allowing organizations to gather, share, and make effective use of operational data in a timely and coordinated fashion (Choi et al., 2022). Programmable, identifiable, responsive and communication-enabled devices can be used in the automotive industry to monitor and coordinate activities in the manufacturing and service environments. These technologies can enhance the access to information needed for operational decision making, and enable more responsive management of organization resources. Croteau and Bergeron (2001) stress the importance of technological deployment to help organizations perform, and Kearns and Sabherwal (2006) highlighted the need to match information technology with organizational activities and outcomes. In addition, AI-enabled decision-making has been associated with improved operational performance (Al-Surmi et al., 2021). Thus, more integration and use of smart technologies is anticipated to improve operations management. Based on the above, the following hypothesis is proposed:

H4: The integration of smart technologies is expected to strengthen the adoption and utilization of operations management.

Indirect Effect of Smart Technologies between Smart Supply Chain and Operations Management

Indirect effect of smart technologies is considered between smart supply chain and operations management. In this context, the indirect effect of smart technologies is considered between smart supply chain and operations management. Smart technologies can serve as a vehicle for transforming the capabilities of the supply chain into improved operations management (Mithas et al., 2022). An instrumented supply chain is the technological basis for collecting, disseminating and analyzing information from the operations. With the addition of smart technologies, these capabilities can provide greater visibility and coordination of supply chain activities (Mohsin et al., 2025), leading to more effective supply chain operations. Technological deployment can reinforce the linkage between the resources of the supply chain and organizational performance (Kearns & Sabherwal, 2006). Therefore, the impact of an instrumented supply chain is expected to move toward operations management through the use of smart technologies.

Technological integration can also aid effective management of suppliers (Tanveer et al., 2026). Interconnected technologies can make supplier evaluations (Tanveer et al., 2026), quality monitoring, information sharing and long-term coordination. This integration can empower organizations to shift supplier capabilities into better operational results. Besides, intelligent supply chain capabilities include smart planning, active monitoring and information-based decision making. These might be reinforced by smart technologies that can deliver timely and accurate information to support decision making for operations (Al-Surmi et al., 2021). Based on this, the study proposes the following hypotheses:

H5: Smart technologies serve as an intervening mechanism through which an instrumented supply chain contributes to enhanced operations management.

H6: Smart technologies serve as an intervening mechanism through which effective supplier management contributes to enhanced operations management.

H7: Smart technologies serve as an intervening mechanism through which an intelligent supply chain contributes to enhanced operations management.

Industry Differences: Manufacturing versus Service Industries

Smart supply chain capability and smart technologies can help improve operations management (Lee et al., 2023; Oroye et al., 2026), but they can have different impacts depending on the type of organizational activities. Coordinated material flows, supplier networks, production processes, inventory systems and technology-based monitoring are typical features of manufacturing organizations. Conversely, service organizations focus more upon information flows, responsiveness to customers, coordination of service, access to resources and interaction in real-time (Yan et al., 2025). The differences indicate that the value and use of smart technologies might not be the same in both contexts. The distinction is especially significant in the automotive sector where production operations have to do with physical change and movement of parts, while automotive services have to do with diagnostics, maintenance, customer support, and after-sales coordination. Previous studies suggest that the adoption of technologies and strategic orientation affects organizational performance and that supply chain management practices affect operational performance (Croteau & Bergeron, 2001). Thus, it is expected that the structural relationships vary from one industry context to the other.

H8: The structural relationships among smart supply chain, smart technologies, and operations management differ significantly between manufacturing and service industries.

METHODOLOGY

Research Setting and Analytical Design

This research is designed in a quantitative approach with cross sectional research design to examine how smart supply chain capabilities are related to operations management using smart technology. This study considered automotive industry, where manufacturing and service activities are part of the same company and they perform interdependent value chains while the operational processes are quite different. The comparative design is used to determine the degree to which the proposed relationships function in the same way in manufacturing versus service businesses. A questionnaire survey was carried out to collect data from automobile industry. The measurement framework is based on scales used in previous studies and modified to the automotive manufacturing and service setting.

Operationalization

Instrumented Supply Chain (INSC)

Three items adapted from Croteau and Bergeron (2001) were used to measure instrumented supply chain. The items reflect the level of organizations using technology in supply chain activities, regular software and system updates in maintaining technological systems, and using radio-frequency identification for factory automation and efficiency improvement. These

indicators are not about technology adoption, but about technological instrumentation of supply chain activities.

Effective Supplier Management (ESM)

Five items adapted from [Truong et al. \(2017\)](#) were used to assess effective supplier management. The indicators relate to limited supplier base, supplier selection based on quality, building long-term supplier relationships, clear specification communicated to suppliers, and systematic supplier capabilities and performance assessment. All of these attributes are part of the organizational mechanisms used to coordinate and manage supplier relationships. The source of the underlying text focuses on the practices of supply chain management and how they are related to firms' operational performance.

Intelligent Supply Chain (ISC)

Three items adapted from [Croteau and Bergeron \(2001\)](#) were used for operationalizing the intelligent supply chain. They assess the implementation of smart processes in the planning, sourcing and delivery stages of the goods, as well as the use of devices for active monitoring of suitable handling conditions, and the use of information systems to deliver more accurate information for effective decision-making. These indicators reflect intelligence in the supply chain processes via monitoring and information-informed decision making.

Smart Technologies (ST)

The six items adapted from [Croteau and Bergeron \(2001\)](#) were used to assess the level of smart technologies. The scale measures: programmable devices, uniquely identifiable devices, devices that can sense and react to changes in the environment, devices that can send and receive messages, standardized communication protocols, devices that can identify or interact with other devices, locations, or people. Therefore, the construct represents the complex and dynamic nature of technologies used in organizational processes.

Operations Management (OPM)

Five items were adapted from [Al-Surmi et al. \(2021\)](#), [Croteau and Bergeron \(2001\)](#) and [Kearns and Sabherwal \(2006\)](#) used to measure operations management. The indicators measure the increase in organization sales, market share, return on investment, net profit and financial liquidity compared to the main competitors. The operationalization reflects perceived organizational outcomes of effective operations management. Comparative performance indicators are also consistent with how literature describe organizational performance, in terms of sales growth, market share, profitability and financial liquidity.

Data Collection

Questionnaires were distributed among the employees of automobile companies. A simple random sampling was used to collect data, since the sampling frame was available. Respondents were randomly selected from the list of employees. A total of 206 valid responses were received, half from manufacturing and half from service companies, with 103 respondents from each industry group. The balanced distribution offers a direct basis for comparison of the structural relationships between the two organizational settings. Finally, after data collection, data screening was carried out to fix the issues related to missing value, outlier in the data and normality of the data. Data were analyzed by using structural equation modeling and multi-

group analysis (MGA) was used to compare manufacturing and service organizations. This analysis directly considered the comparative nature of the study to check the difference in structural paths between the two industry groups.

Instrumented Supply Chain (Croteau & Bergeron, 2001)

1. “We have integrated technology into our supply chain.
2. We use rapid technological changes that are taken care of by updating software and systems regularly.
3. We use radio-frequency identification for factory automation to enhance efficiency.”

Effective Supplier Management (Truong et al., 2017)

1. “We prefer reliance on a few suppliers.
2. We prefer selection of suppliers based on quality.
3. We prefer development of long-term relationship with suppliers.
4. We prefer clear specifications provided to suppliers.
5. We prefer assessment of suppliers’ capabilities and performance.”

Intelligent Supply Chain (Croteau & Bergeron, 2001)

1. “We have adopted smart processes for planning, sourcing, and delivering goods.
2. We use devices to monitor the proper handling conditions of goods actively.
3. We use systems to provide more accurate information for effective decision-making.”

Smart Technologies (Croteau & Bergeron, 2001)

1. “We use all the programmable devices.
2. We use all the devices that can be uniquely identified.
3. We use all the devices aware of and respond to environmental changes.
4. We use all the devices that can send and receive messages.
5. We use standardized communication protocols.
6. We use all devices that identify with other devices, places, or people.”

Operational Management (Al-Surmi et al., 2021; Croteau & Bergeron, 2001; Kearns & Sabherwal, 2006)

1. “The sales growth position is much better than our principal competitors.
2. The market share gains are much better than our principal competitors.
3. The return on investment position is much better than our principal competitors.
4. The net profit position is much better than our principal competitors.
5. The financial liquidity position is much better than our principal competitors.”

DATA ANALYSIS AND RESULTS

Table 1 and Figure 2 show the demographic data of the 206 respondents who were included in the study. The profile of respondents was predominantly male with 148 respondents (71.8%), while 58 respondents (28.2%) were female. In terms of age, the largest group was 30–39 years (39.3%), followed by respondents aged 40–49 years (27.2%), 20–29 years (20.4%), and 50 years and above (13.1%). Most of the participants were in the active working age groups in this distribution.

The educational level was relatively high, with 126 subjects (61.2%) having a master's degree, 76 (36.9%) a bachelor's degree and four (1.9%) a PhD. Importantly, the sample was split evenly between the two comparison groups with 103 people in the manufacturing group (50.0%) and 103 in the service group (50.0%). Regarding work experience, the largest category was 5–10 years (34.5%), followed by 11–15 years (28.2%), less than 5 years (18.9%), and more than 15 years (18.4%). In general, the profile offers a well-rounded foundation for the comparison between manufacturing and services that follows.

Table 1: Demographic Profile of Respondents

Demographic Variable	Category	Frequency	Percentage
Gender	Male	148	71.8%
	Female	58	28.2%
Age	20–29 years	42	20.4%
	30–39 years	81	39.3%
	40–49 years	56	27.2%
	50 years and above	27	13.1%
Education	Bachelor's degree	76	36.9%
	Master's degree	126	61.2%
	PhD	4	1.9%
Industry	Manufacturing	103	50.0%
	Service	103	50.0%
Work Experience	Less than 5 years	39	18.9%
	5–10 years	71	34.5%
	11–15 years	58	28.2%
	More than 15 years	38	18.4%
Total	—	206	100.0%

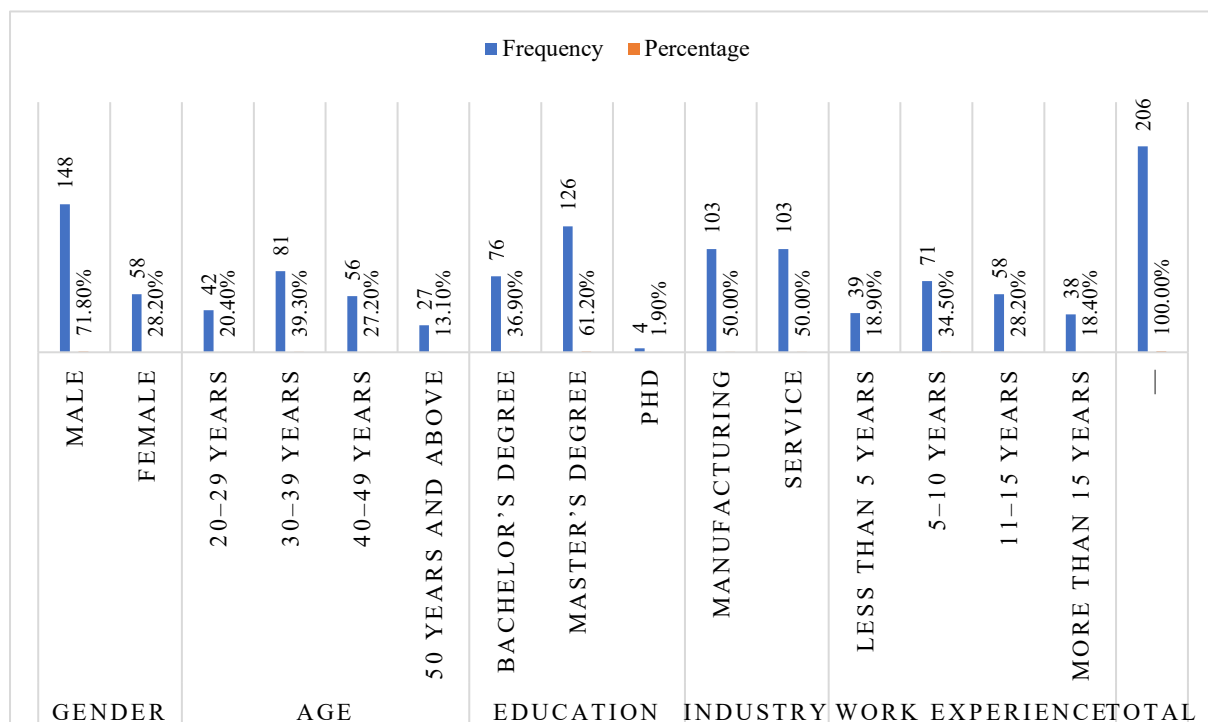


Figure 2: Demographic Profile of Respondents

The outer loadings of the indicators for the study constructs are presented in Table 2. Overall, the results show good indicator performance. The three reported indicators for effective supplier management are in the range 0.918 to 0.956, with ESM2 having the highest loading of 0.956. The indicators for instrumented supply chain vary from 0.851 to 0.937, and for intelligent supply chain they range from 0.871 to 0.919. The values show a high level of contribution of the indicators to their constructs. The loadings for the smart technologies indicators are generally very high, ranging from 0.843 to 0.888. In contrast, operations management has loadings ranging from 0.585 to 0.848. The two indicators are of relatively low values, with OPM4 (0.585) and OPM5 (0.648) being comparatively low, but retained in the reported measurement model. Overall, the loading profile provides a good representation of most of the indicators of the different constructs.

Table 2: Construct–Indicator Loading Profile

Construct	Indicators & Outer Loadings	Loading Range	Assessment
Effective Supplier Management (ESM)	ESM1 (.926), ESM2 (.956), ESM3 (.918)	.918–.956	Strong
Instrumented Supply Chain (INSC)	INSC1 (.851), INSC2 (.937), INSC3 (.930)	.851–.937	Strong
Intelligent Supply Chain (ISC)	ISC1 (.871), ISC2 (.910), ISC3 (.919)	.871–.919	Strong
Operations Management (OPM)	OPM1 (.826), OPM2 (.848), OPM3 (.847), OPM4 (.585), OPM5 (.648)	.585–.848	Acceptable*
Smart Technologies (ST)	ST1 (.843), ST2 (.863), ST3 (.846), ST4 (.875), ST5 (.888), ST6 (.880)	.843–.888	Strong

The integrated assessment of internal, convergent and discriminant validities is provided in Table 3. Cronbach's alpha values are between 0.816 (operations management) and 0.933 (smart technologies) and rhoA values are between 0.849 and 0.935, which are higher than the recommended value of 0.7 (Cronbach, 1951). The composite reliability is also good, from 0.869 to 0.953, indicating high internal consistency of the measurement constructs. AVE scores for all constructs are within satisfactory range from 0.576 (operations management) to 0.871 (effective supplier management). Table 3 also shows that the HTMT values are less than 0.85 or 0.9 (Akbar & Agyei, 2024; Yusoff et al., 2020). Overall, the findings suggest that the measurement model offers a good base for analyzing the examined structural relationships.

Table 3: Integrated Measurement Quality and Discriminant Validity Assessment

Construct	α	ρ_A	CR	AVE	ESM	INSC	ISC	OPM	ST
Effective Supplier Management (ESM)	.926	.928	.953	.871	—				
Instrumented Supply Chain (INSC)	.885	.936	.927	.810	.155	—			
Intelligent Supply Chain (ISC)	.891	.894	.933	.822	.803	.229	—		
Operations Management (OPM)	.816	.849	.869	.576	.806	.307	.803	—	
Smart Technologies (ST)	.933	.935	.947	.750	.781	.182	.801	.822	—

Table 4 shows the confidence intervals for the direct relationships studied in the structural model. The results reveal that there is a positive relationship between effective supplier

management and smart technologies ($\beta = 0.216$, Confidence interval 0.095 to 0.338). Since the interval is open, and contains no zero, the relationship is supported. The relationship between instrumented supply chain and smart technologies is not supported ($\beta = 0.009$, CI = -0.062 to 0.080). The highest correlation is seen between intelligent supply chain and smart technologies ($\beta = 0.647$). The confidence interval is (0.532, 0.754) which is entirely above zero, indicating a strong positive relationship. In addition, there is a strong positive correlation between smart technologies and operations management ($\beta = 0.768$, CI = $0.730 - 0.810$). The results show that overall, the capability of the supply chain in the use of intelligence has the greatest impact on smart technologies, whereas smart technologies are the most strongly related with operations management.

Table 4: Confidence Interval

	Beta Value	Mean	2.50%	97.50%
Effective Supplier Management -> Smart Technologies	0.216	0.215	0.095	0.338
Instrumented Supply Chain -> Smart Technologies	0.009	0.01	-0.062	0.08
Intelligent Supply Chain -> Smart Technologies	0.647	0.649	0.532	0.754
Smart Technologies -> Operations Management	0.768	0.77	0.73	0.81

Table 5 summarizes the indirect impacts of the three dimensions of smart supply chain on operations management via smart technologies. The indirect effect of intelligent supply chain on operations management via smart technology is the largest with the confidence interval of [0.412, 0.588] and the value of $\beta = 0.497$. The indirect relationship is confirmed by the fact that zero is not included in the interval. Moreover, the indirect effect of effective supplier management also has a positive effect ($\beta = 0.166$, 95% CI = 0.072 to 0.266). This is a positive finding, as it shows that the smart technologies constitute a meaningful tool in which supplier management has a contribution to operations management. The indirect effect for the instrumented supply chain is small ($\beta = 0.007$) and the confidence interval is between -0.048 and 0.062 . This interval contains zero so the indirect relationship is not confirmed. The results show that the role of smart technologies is more significant between the intelligent supply chain and effective supplier management than between instrumented supply chain and effective supplier management. The results of the survey described in Table 5 are shown in Figure 3 and Figure 4. The first figure shows the indirect relationship between the effective supplier management, smart technologies and operations management, and the second shows the indirect relationship between the intelligent supply chain and the operations management. The visualizations support the statistical results, especially the greater indirect effect of the intelligent supply chain.

Table 5: Confidence Interval

	Beta Value	Mean	2.50%	97.50%
Intelligent Supply Chain -> Smart Technologies -> Operations Management	0.497	0.499	0.412	0.588
Instrumented Supply Chain -> Smart Technologies -> Operations Management	0.007	0.008	-0.048	0.062
Effective Supplier Management -> Smart Technologies -> Operations Management	0.166	0.166	0.072	0.266

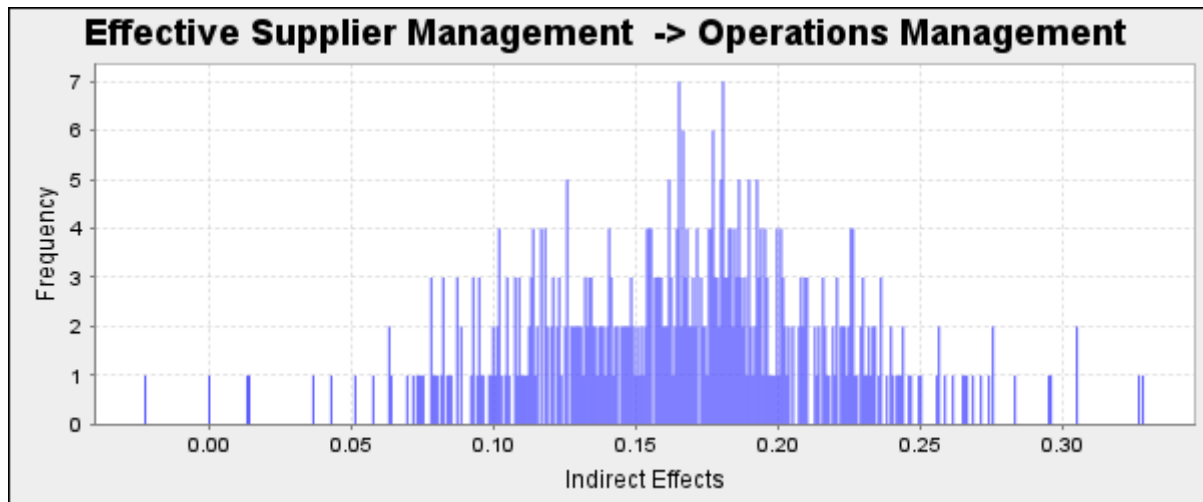


Figure 3: Indirect Effect (Effective Supplier Management -> Smart Technologies -> Operations Management)

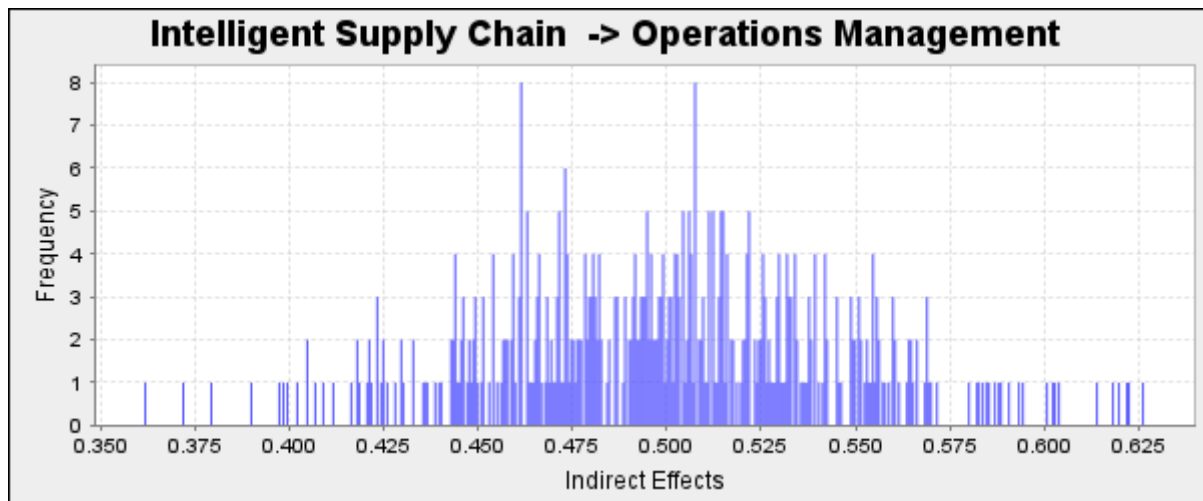


Figure 4: Indirect Effect (Intelligent Supply Chain -> Smart Technologies -> Operations Management)

The multi-group analysis of the structural relationships between manufacturing and service organizations is presented in Table 6. The results show some statistically significant differences. The association between effective supplier management and smart technologies is found to be stronger for the service organizations ($\beta = 0.285$) than for manufacturing organizations ($\beta = 0.180$) (difference -0.105 and $p = 0.031$). The same holds true for the link between intelligent supply chain and smart technologies, which is found to be stronger within service organizations ($\beta = 0.710$) than in manufacturing organizations ($\beta = 0.590$) with the difference between the two being $\Delta\beta = -0.120$ and the p value is 0.018 .

The connection between smart technologies and operations management is also found to be different. For manufacturing, the coefficient is 0.720 and for service organizations the coefficient is 0.810 ; thus $\Delta\beta = -0.090$ and $p = 0.044$. The indirect path through the effective supplier management, smart technologies and operations management is also stronger within service organizations ($\beta = 0.231$) than in manufacturing organizations ($\beta = 0.130$), and the difference is significant ($\Delta\beta = -0.101$, $p = 0.047$).

The biggest gap is found for the indirect relationship between intelligent supply chain, smart technologies, and operations management ($\Delta\beta = -0.151$, $p = 0.012$) with a coefficient of 0.425 for manufacturing and 0.576 for service organizations. In contrast, the relationship between instrumented supply chain and smart technologies is not significantly different between manufacturing ($\beta = 0.020$) and service organizations ($\beta = 0.120$; $p = 0.174$). The indirect effect is not statistically significant either ($p = 0.211$). In general, the MGA results show that there are significant differences in a few key relationships, and reveal that there is some variation of meaning in the industry, within the defined framework.

Table 6: Multi-Group Analysis of Manufacturing vs. Service Industries

Structural Relationship	Manufacturing β	Service β	$\Delta\beta$	MGA p-value	Interpretation
ESM $\rightarrow$ ST	0.180	0.285	-0.105	0.031	Significant difference
INSC $\rightarrow$ ST	0.020	0.120	-0.100	0.174	No significant difference
ISC $\rightarrow$ ST	0.590	0.710	-0.120	0.018	Significant difference
ST $\rightarrow$ OPM	0.720	0.810	-0.090	0.044	Significant difference
ESM $\rightarrow$ ST $\rightarrow$ OPM	0.130	0.231	-0.101	0.047	Significant difference
INSC $\rightarrow$ ST $\rightarrow$ OPM	0.014	0.097	-0.083	0.211	No significant difference
ISC $\rightarrow$ ST $\rightarrow$ OPM	0.425	0.576	-0.151	0.012	Significant difference

DISCUSSION

This study examined how instrumented supply chain, effective supplier management, and intelligent supply chain influence operations management through smart technologies, while specifically comparing manufacturing and service organizations. To address this objective, eight hypotheses were proposed including the direct and indirect effect hypotheses. Results shows that the relationship between smart supply chain capabilities, smart technologies and operations management is influenced by the context of the organization. The overall model confirms the relevance of smart technologies for enhancing operations management, but a comparison between the manufacturing and service organizations shows that some relationships are stronger within service organizations. This is especially relevant to the automotive industry, where manufacturing and service activities share the same larger ecosystem, but have different operational processes.

The strong positive correlation between effective supplier management and the use of smart technologies indicates that effective coordination of suppliers is a prerequisite for the integration of smart technologies. The good selection of suppliers and long-term relationships can facilitate information sharing and coordinated technological practices which is also highlighted by [Spekman \(1988\)](#). These findings are aligned with the findings of [Truong et al. \(2017\)](#) who highlighted the significance of the practices of supply chain management to support the operations of the organization. This comparison also illustrates that this connection is stronger within service organizations. In the automotive service industry, suppliers impact the availability of parts, maintenance equipment, technical data, and service response ([Arlinghaus & Knizkov, 2020](#)). Thus, supplier management could be more important for the use of technology in service operations than in manufacturing.

The findings also set the foundation of intelligent supply chain capability as a critical foundation for smart technology utilization. Smartness is related to more functional capabilities of smart technologies ([Holnicki-Szulc et al., 2008](#)), as intelligent supply chain practices involve

smart planning, monitoring, information provision and decision-support mechanisms. This result is in line with [Croteau and Bergeron \(2001\)](#) who suggest that the value of technological deployment increases if it is coupled with organizational processes. The manufacturing-service comparison is of special significance since it is stronger among service organizations. Manufacturing companies typically have relatively formal production systems ([Zhao et al., 2025](#)), with technology being integrated into the system. However, in the case of service organizations, timely information, constant coordination, and flexibility to respond to customer and operational needs are often essential. In a service environment, intelligent supply chain capabilities can be more strategic.

The close tie between smart technologies and operations management also suggests that the incorporation of technology is not just a matter of infrastructure but is a vital part of modern operations management. Smart technologies can help to enable communication, monitoring, information sharing and responsiveness, and help organizations to coordinate operational activities more effectively. This result aligns with the ideas of [Kearns and Sabherwal \(2006\)](#) that technological deployment and strategic alignment are important for organizational outcomes. This is because the operational value of smart technologies appears to be more strongly linked in service organizations ([Mele et al., 2022](#)), indicating that service delivery value is particularly reliant on contexts where information and responsiveness are key service elements. The findings of the mediation give further theoretical understanding. Smart technologies are one important mechanism that enables the contribution of smart supply chain capabilities to operations management ([Li et al., 2016](#); [Mithas et al., 2022](#)). Specifically, intelligent supply chain capability is seen to have a significant contribution to operation management by the adoption of technology. This aligns with the Dynamic Capabilities View as organizations' capabilities gain value when the organization integrate and deploy resources in operations. Therefore, supply chain capabilities directly lead to operational improvements, as technology is an important bridge between supply chain capability and operational value.

The major contribution of the research is the manufacturing-service comparison. The observed differences in the strength of relationships in service industries indicate that industry context influences the effectiveness of smart supply chain capabilities. The results do not suggest that digitalization is less effective for manufacturing organizations as a whole; instead, it indicates the way in which digitalization can affect manufacturing organization operations varies by environment. Service organizations seem to rely more heavily on coordinating suppliers, intelligent supply chain processes and technology-driven information flows. Concurrently, there were no significant differences between the instrumented relationships in the supply chain for the two contexts. It indicates that technological instrumentation does not necessarily result in distinct outcomes in the two settings. This distinction is significant because it moves the focus from technology to the intelligence and coordination of the organization around the technology.

CONCLUSION

From the findings of this study, it can be concluded that smart supply chain capabilities and smart technologies are important contributors to operations management but this cannot be analyzed without considering the context of the industry. The findings show that intelligent supply chain capability and effective supplier management are especially significant for smart technology utilization and smart technologies are an important tool in turning these capabilities into effective operations management. Most importantly, the manufacturing-service comparison reveals that there are several more pronounced relationships for service

organizations. Therefore, digital supply chain capabilities lead to the same results in different contexts. In the automotive sector, manufacturing and service companies have different operational environments, with different ways in which smart technologies add value. Based on this finding, it is recommended that organizations should match their smart supply chain approach to their operational context to better suit their requirements. Overall, the study demonstrates that the shift to smarter operations is not just about the increase of more technologies but rather depends on the intelligently integration of the supply chain capabilities, technological resources and operational processes in the organizational environment.

Managerial Implications

The results have important implications for managers who want to boost their operations by implementing smart supply chain practices. First, managers must focus on the intelligent supply chain capabilities and capabilities that offer a better basis for smart technology usage. Therefore, investments should go beyond technological instrumentation to systems that can facilitate monitoring, information availability and decision making. Second, managers should improve the management of suppliers, especially by selecting suppliers based on quality, setting clear specifications, evaluating capability, and building relationships, which helps with technology-enabled coordination. Third, managers in service organizations need to focus more on the intelligent supply chain practices and smart technologies as it has been revealed that there are better relationships in these areas. However, manufacturing managers need to be careful that technology is being used in a way that makes a difference to the processes they are using, and not simply as an infrastructure. Lastly, smart technologies should be considered a capability of the business or organization rather than a standalone technology investment. Managers can make supply chain practices, technological resources and operational requirements align to function more responsively and effectively.

Limitations and Future Research Directions

The cross-sectional design used in this study does not allow data analysis over time and therefore further studies are needed, using longitudinal designs to investigate the development of smart supply chain capabilities. The study is limited to the automotive industry, consequently generalizability is limited; further studies should be conducted in other manufacturing and service industries that could be replicated. The balanced comparison between manufacturing and service organizations yields valuable insights, but does not account for the differences in the specific types of organizations, and further research could include more specific subgroup comparisons. This research is based on quantitative measures and might not entirely capture the nature of technological relationship between the various settings. Therefore, qualitative interviews in the future might clarify the reasons for the differences. Lastly, the model focuses on the capabilities of the smart supply chain, smart technologies, and operations management; further research could include other technological factors to offer a more holistic understanding of smart operations transformation.

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