Impact of Supply Chain Complexity on Supply Chain Performance: Moderating Role of Information Technology Infrastructure

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ABSTRACT

The study sought to assess the influence of supply chain complexities on the performance of manufacturing companies in Saudi Arabia, while also evaluating the moderating role of information technology infrastructure. A cross-sectional research design was utilized to gather quantitative data from 370 employees across various manufacturing firms. Descriptive and inferential analyses were conducted using SPSS and Smart PLS software. The results indicated that upstream, operations, downstream, external, and internal supply chain complexities have positive and significant effects on supply chain performance. Furthermore, the study demonstrated that information technology infrastructure significantly moderates the relationship between all supply chain complexities and performance, underscoring the critical role of IT infrastructure in enhancing supply chain outcomes. These findings contribute theoretically by advancing our understanding of the interplay between technological and supply chain complexities within supply chain management. Practically, the results emphasize the importance for manufacturing firms to invest in robust IT systems and foster strong collaborative relationships to improve performance and secure a competitive advantage. Future research could explore these findings in different geographical contexts and incorporate additional supply chain complexities to examine potential variations in results.

Keywords: Supply Chain Complexities, Supply Chain Collaboration, Supply Chain Performance, Saudi Arabia.

INTRODUCTION

In today's competitive landscape, supply chain performance is crucial for an organization to efficiently and effectively deliver goods from manufacturers to end consumers. This performance is often characterized by delivery speed, cost management, and inventory control (Christopher, 2016). Effective management of these factors not only optimizes resource utilization and reduces costs but also enhances responsiveness to market demands and improves overall performance (Van Hoek, 2021). Conversely, poor supply chain performance can result in increased operational costs, missed delivery deadlines, and decreased customer satisfaction. Inefficiencies in the supply chain can propagate throughout the system, leading to lost revenue, damaged customer relationships, and a diminished market share (Kumari et al., 2024). To enhance supply chain performance, managing supply chain complexities is essential, as it influences efficiency, agility, and risk management (Iftikhar et al., 2023). High complexity can result in increased costs and delays due to intricate processes, whereas simplifying the supply chain can improve performance by enhancing coordination, reducing costs, and accelerating response times (Iftikhar et al., 2023). Additionally, effective management of information technology, through enabling efficient data integration, can facilitate better coordination, minimize operational bottlenecks, and enhance overall performance (Kumar et al., 2023). Technologies such as advanced analytics, cloud computing, and automation systems further enable organizations to streamline operations, forecast demand with greater accuracy, and optimize inventory levels (Yang et al., 2021).

Furthermore, information technology enhances supply chain management by enabling real-time data sharing and streamlining communication among stakeholders (Gopal et al., 2024). It also improves inventory control and demand planning through advanced analytics and automation, leading to enhanced performance. IT solutions facilitate shipment tracking and ensure transparency, thereby reducing errors and increasing efficiency (Yousefi & Tosarkani, 2023). Studies have also demonstrated that effective IT infrastructure can manage complexities by providing integrated systems that enhance coordination and information flow (Mitra et al., 2023; Zhang et al., 2021). As supply chain complexities increase, leveraging advanced IT solutions becomes essential for managing these complexities and improving performance by enabling more agile, responsive, and efficient operations. A cohesive technological environment reduces supply chain complexities, leading to more efficient operations and improved performance (Yousefi & Tosarkani, 2023; Zhao et al., 2020). Additionally, information technology supports better risk management by offering predictive analytics and real-time monitoring to anticipate and mitigate disruptions (Gopal et al., 2024). Therefore, this study focuses on examining the moderating effect of information technology infrastructure on the relationship between supply chain complexities and supply chain performance.

Various studies have investigated the relationships among supply chain complexities, information technology infrastructure, and supply chain performance, revealing several research gaps. Initially, researchers such as Yousefi and Tosarkani (2023), Metwally et al. (2024), and Bier et al. (2020) examined the direct effects of supply chain complexity on performance indicators. Additionally, studies by Acosta-Prado and Tafur-Mendoza (2024) and Awwad and El Khoury (2024) focused on the impact of information technology infrastructure on performance. However, there has been limited research on the moderating effects of supply chain complexities on performance and the role of information technology infrastructure as a moderating factor. This gap highlights the need for a more nuanced understanding of how information technology infrastructure interacts with supply chain complexities to influence performance. Previous studies on the relationship between supply chain complexities and performance have produced mixed results (Guntuka, Corsi, & Cantor, 2024; Hamidu et al., 2024; Iftikhar et al., 2023). This inconsistency underscores the importance of exploring information technology infrastructure as a moderating variable, which may enhance the impact of supply chain complexities on performance. Supporting this perspective, Hu et al. (2024) demonstrated that incorporating information technology infrastructure as a moderating factor can leverage technological advancements to improve performance. Consequently, this study employs information technology as a moderating variable to address these research gaps.

Moreover, existing literature has examined various components of supply chain complexities, such as upstream supply chain complexity, downstream supply chain complexity, and operations supply chain complexity (Chand et al., 2022). Other studies have explored internal and external supply chain complexities (Bozarth et al., 2009). However, these studies have not integrated these components into a single, comprehensive model. Furthermore, while previous research has predominantly focused on contexts outside Saudi Arabia, there has been limited attention given to the manufacturing sector within the country. This geographical gap presents an opportunity for further research to investigate how supply chain complexities and information technology infrastructure impact performance in this region, potentially uncovering insights unique to the local industry context (Al-Refaie & Abdelrahim, 2021). To address these gaps, the current study aims to examine the impact of supply chain complexities on the performance of manufacturing companies in Saudi Arabia and assess the moderating effect of information technology. This study contributes to the literature from both theoretical and practical perspectives. Theoretically, it offers a novel combined model that integrates various components of supply chain complexities, filling a gap left by previous studies that focused on different countries and sectors.

Therefore, incorporating information technology as a moderating variable within a complex model offers a more comprehensive understanding of how supply chain complexities influence supply chain performance. This approach advances existing theories by integrating information technology to enhance the management of supply chain complexities and improve performance outcomes. From a practical perspective, these insights highlight the necessity of developing strong collaborative relationships among supply chain partners to fully realize the benefits of IT investments. Organizations should focus on fostering collaboration to ensure effective IT integration and optimize performance, especially within complex supply chains. The article is structured into four chapters: Chapter Two reviews the literature and establishes the study hypotheses; Chapter Three details the research design and sampling techniques used for data collection; Chapter Four presents the data analysis and results interpretation; and the final chapter discusses the findings, research limitations, and future research directions.

LITERATURE REVIEW

Supply Chain Performance

Supply chain performance (SCP) is a critical concern for organizations, as it encompasses the enhancement of supply chain operations to efficiently deliver products from suppliers to customers. Key performance metrics include delivery speed, cost control, and inventory management (Han et al., 2020). Effective supply chain management ensures timely delivery of products at minimal costs, which enhances competitive advantage (van Hoek, 2021). Furthermore, well-managed supply chains can reduce operational risks, optimize resource utilization, and foster better collaboration among stakeholders, which is essential for maintaining a resilient and adaptable business model (Kumari et al., 2024). Previous studies have underscored that improving supply chain performance is vital for achieving sustainable growth and meeting various strategic objectives.

Supply Chain Complexity

Supply chain complexity encompasses the management of interconnected processes and stakeholders that directly or indirectly influence the flow of goods from distributors to end consumers (Isik, 2011). This complexity is composed of several dimensions, each presenting distinct challenges within the supply chain process. The first dimension is upstream supply chain complexity, which involves coordinating with various suppliers according to their individual requirements and dealing with variability in delivery and quality, all of which can impact supply chain performance (Chand et al., 2022 ; Guntuka et al., 2024). External supply chain complexity includes factors beyond the organization's control, such as regulatory changes, economic fluctuations, and geopolitical issues, which can introduce uncertainty and require strategic and operational adjustments (Chand et al., 2022). Internal supply chain complexity refers to the integration of various internal functions, including procurement, production, logistics, and resource management (Bozarth et al., 2009). Finally, operations supply chain complexity pertains to daily challenges related to inventory management (Bozarth et al., 2009). Various authors have emphasized that managing these dimensions is crucial for optimizing supply chain performance (Bozarth et al., 2009). These studies suggest that effectively addressing supply chain complexities is essential for enhancing overall supply chain performance.

Hypothesis Development

Empirical studies investigating the relationship between upstream supply chain complexity (USCC) and SCP have produced varied results. Nenavani and Jain (2022) found a positive and significant impact of USCC on SCP, suggesting that this relationship warrants further exploration in different countries to enhance the robustness of the model. In contrast, Ivanov (2024) identified that disruptions in upstream processes, such as delays in raw material supply or changes in supplier capabilities, could negatively affect SCP. Other research has also reported a positive and significant impact of USCC on performance (Fatorachian & Kazemi, 2021). Conversely, (Akın Ateş et al, 2022; Hamidu et al., 2024) found a negative impact of USCC on SCP. These conflicting findings highlight the critical need for effective management of upstream complexities to improve supply chain performance. Consequently, the study proposes the following research hypotheses,

H1: *SCP significantly influenced by USCC.*

Operations supply chain complexity (OSCC) plays a crucial role in influencing SCP through factors such as quality control and production processes, which are essential for enhancing SCP (Bag et al., 2020). Akın Ateş et al. (2022) found a positive and significant impact of OSCC on SCP, noting that OSCC can lead to bottlenecks and delays in production, which affect overall supply chain efficiency and customer satisfaction. Additionally, Liu et al. (2021) demonstrated that OSCC, particularly in manufacturing processes and inventory management, directly impacts lead times and production costs, underscoring the importance of effective operational strategies to mitigate challenges and improve SCP. Other studies, such as Iftikhar et al. (2023), have also found a positive impact of OSCC on SCP and emphasized the need for companies to prioritize the management of OSCC to enhance SCP. Based on these findings, the following hypothesis is proposed,

H2: *SCP significantly influenced by OSCC.*

Downstream supply chain complexity (DSCC) involves various distribution challenges and customer demands that significantly affect SCP. Akın Ateş et al. (2022) found that uncertainties in demand forecasting and inventory management downstream can lead to stockouts or excess inventory, impacting cost-effectiveness and SCP. Alogla (2021) emphasized that effectively managing downstream complexities is crucial for maintaining service levels and meeting customer expectations, which can enhance SCP. Additionally, Chand et al. (2022) reported a positive impact of DSCC on SCP, arguing that greater emphasis on managing DSCC can improve SCP. Based on these findings, the following hypothesis is proposed,

H3: *SCP significantly influenced by DSCC.*

External supply chain complexity (ESCC), including market dynamics and regulatory changes, poses significant challenges that impact SCP (Gupta et al., 2020). Alogla (2021) found that ESCC can lead to supply chain disruptions and operational inefficiencies, affecting performance. Furthermore, Holloway (2024) highlighted that uncertainties in global markets and changes in trade policies necessitate adaptive supply chain strategies to mitigate risks and maintain SCP. Conversely, Monostori (2021) reported a negative impact of ESCC on SCP and recommended that organizations focusing on improving SCP should prioritize the management of external supply chain complexities. However, Chand et al. (2022) found a positive and significant impact of ESCC on SCP, emphasizing the importance of managing ESCC to enhance SCP. Based on these findings, the following hypothesis is proposed,

H4: *SCP significantly influenced by ESCC.*

Internal supply chain complexities (ISCC), including organizational structure and process inefficiencies, play a crucial role in enhancing SCP (Kamble & Gunasekaran, 2020). Hidayata et al. (2024) demonstrated that managing ISCC is vital for improving operational efficiency and reducing costs within the supply chain. Additionally, Monostori (2021) emphasized that complexities in internal processes and decision-making frameworks directly affect supply chain responsiveness and agility, which in turn influences SCP. Akın Ateş et al. (2022) also found a positive and significant impact of ISCC on SCP, suggesting that future research could explore this relationship in other developing countries with weaker SCP and investigate additional moderating effects. These findings underscore the importance of efficient internal operations for enhancing supply chain performance.

H5: *SCP significantly influenced by ISCC.*

Existing literature has consistently found a positive and significant impact of supply chain complexities (SCC) on SCP (Al-Rawashdeh & Jawabreh, 2023). Fatorachian and Kazemi (2021) also established a significant relationship between supply chain management and SCP, suggesting that this relationship could be further explored with the inclusion of IT as a moderating variable. Similarly, Iftikhar et al. (2023) found a positive and significant impact of SCC on SCP, highlighting the potential for future research to include additional IT-related factors. Zeng et al. (2020) demonstrated that IT-enabled supplier integration enhances supply chain responsiveness and resilience, thus improving performance despite upstream disruptions. Empirical studies have further confirmed the important role of IT infrastructure (ITI) in increasing SCP (Gu et al., 2021). ITI enhances visibility, efficiency, and decision-making capabilities, which in turn boosts SCP. Sood and Jain (2022) noted that investments in IT systems, such as advanced analytics, contribute to better supply chain integration and responsiveness. Additionally, Foltean and van Bruggen (2022) showed that ITI enables automation and data-driven insights, leading to cost reductions, improved customer service, and competitive advantages. Studies by Kamble et al. (2023) also support the significant impact of ITI on SCP, emphasizing the potential for IT to be used as a moderating variable in future research. Furthermore, Li et al. (2023) found that ITI in risk management and predictive analytics helps organizations anticipate and mitigate external disruptions, enhancing SCP. Research on the moderating effect of ITI has also been conducted, with studies by Aliffandi et al. (2023) and Uyar et al. (2021) confirming a positive and significant moderating effect, while suggesting further exploration with additional variables. Based on these findings, the study proposes the following hypothesis,

H6: *SCP significantly influenced by USCC with moderating effect of ITI.*
H7: *SCP significantly influenced by OSCC with moderating effect of ITI.*
H8: *SCP significantly influenced by DSCC with moderating effect of ITI.*
H9: *SCP significantly influenced by ESCC with moderating effect of ITI.*
H10: *SCP significantly influenced by ISCC with moderating effect of ITI.*

RESEARCH METHODOLOGY

The research aimed to examine the impact of supply chain complexities on the performance of manufacturing companies in Saudi Arabia, with a focus on the moderating effect of information technology. A deductive quantitative approach was employed for this study. Quantitative research is advantageous for its statistical reliability and generalizability through numerical data, enabling precise measurement of variables. This contrasts with qualitative research, which provides rich, contextual insights but may lack the statistical rigor and broad applicability inherent in quantitative methods (Plonsey et al., 2007). Consequently, the researchers selected a quantitative approach. Additionally, a cross-sectional research design was utilized. This design is efficient and cost-effective, providing a snapshot of data at a single point in time. In contrast, longitudinal studies track changes over time, offering deeper insights into trends and causal relationships but requiring more extensive time and resources (Rindfleisch et al., 2008). Therefore, the researchers opted for a cross-sectional design to achieve their research objectives efficiently.

Data Collection Procedure

Data for the study were collected using a self-administered questionnaire distributed among employees of manufacturing companies in Saudi Arabia. Two primary sampling techniques are available: probability sampling, which is used when the population is known, and non-probability sampling, which is appropriate when the population is unknown. This study employed a non-probability convenience sampling technique. This approach allows for efficient and practical data collection by selecting readily accessible participants from the workforce (Etikan et al., 2016). The choice to focus on manufacturing companies is strategically significant due to their key role in Saudi Arabia's economic diversification and industrial growth. A sample size of 450 was determined to enhance statistical power and the reliability of the results. The return of 370 completed surveys provided a robust dataset with a high response rate, minimizing potential bias and increasing the study's generalizability (Rahi, Alnaser, & Abd Ghani, 2019). Consequently, this response rate is considered sufficient for the study's objectives.

Questionnaire Development and Research Framework

The study used a tool adapted from prior research to evaluate supply chain complexities and performance across five dimensions: upstream, downstream, external, internal, and operational. Upstream complexity was measured with 3 items, operational with 4 items, downstream with 3 items, and external with 3 items, all adapted from (Chand et al., 2022). Internal supply chain complexity was measured with 5 items adapted from (Bozarth et al., 2009). Information technology infrastructure was assessed with 3 items based on the work of (Jabbouri et al., 2016). Supply chain performance was measured with 5 items derived from (Qrunfleh & Tarafdar, 2014). The survey employed a five-point Likert scale, with responses ranging from 1 (strongly disagree) to 5 (strongly agree). The relationships among these constructs are illustrated in Figure 1.

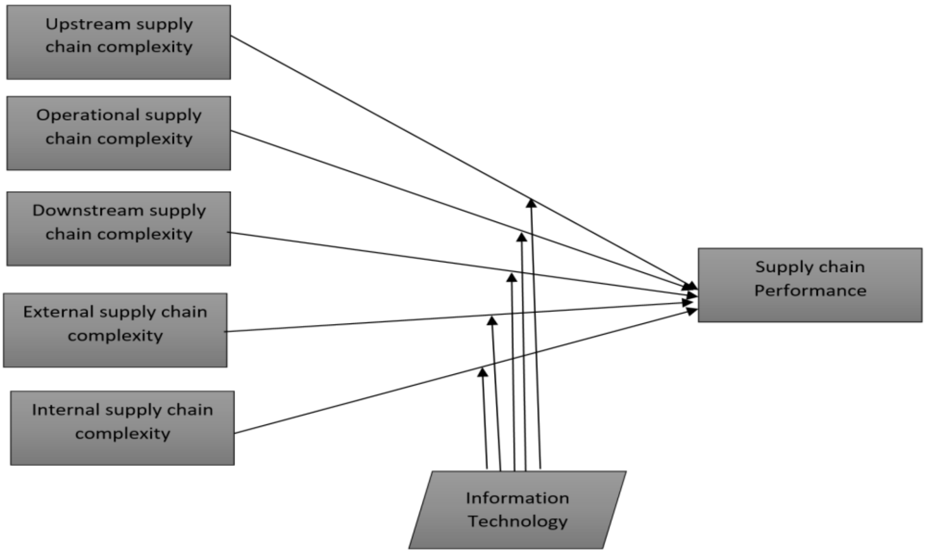

Figure 1: Conceptual Framework

Descriptive Statistics

Table 1 presents the descriptive statistics for the study variables. The highest mean score of 4.23 is observed for ITI, which also exhibits the lowest standard deviation of 0.61, indicating a generally positive perception with minimal variability among respondents. Conversely, ESCC has the lowest mean score of 2.93, suggesting a less favourable view compared to other complexity dimensions. SCP and SCC have relatively high mean scores of 3.94 and 3.70, respectively, reflecting a generally positive assessment with moderate variability. In contrast, USCC and OSCC exhibit lower mean scores, with USCC showing the greatest variability (standard deviation of 0.91), indicating a broad range of opinions regarding upstream complexities. All descriptive statistics are detailed in Table 1.

Table 1: Descriptive Statistics

Variable	Mean	Standard Deviation	Min	Max
USCC	3.21	0.91	1	5
OSCC	3.53	0.78	1	5
DSCC	3.81	0.73	1	5
ESCC	2.93	0.81	1	5
ISCC	3.63	0.93	1	5
ITI	4.23	0.61	1	5
SCP	3.94	0.83	1	5
SCC	3.71	0.89	1	5

Note: "DSCC- Downstream Supply Chain Complexity, ESCC-External Supply Chain Complexity, USSC-Upstream Supply Chain Complexity, , ISCC- Internal Supply Chain Complexity, ITI-information technology infrastructure, OSCC- Operations Supply Chain Complexity, SCP-Supply chain performance, SCC-supply chain collaboration"

Convergent Validity

Convergent validity in the measurement model, which indicates construct validity, is assessed using several criteria, including Cronbach's alpha coefficient (α), CR, and AVE (Hair et al., 2017). Factor loadings indicate the strength and direction of the relationships between observed variables and constructs. Values exceeding 0.7 are generally considered to reflect strong associations and effective measurement of the intended constructs (Hair et al., 2017). Cronbach's alpha measures internal consistency, with values above 0.7 signifying good reliability and suggesting that the items measure the same underlying construct consistently (Hair Jr et al., 2020). CR evaluates the reliability of the measurement model, with values greater than 0.7 considered acceptable, indicating consistent measurement of the latent construct. For AVE, a value greater than 0.5 is recommended to ensure adequate convergent validity, reflecting that the construct explains a reasonable proportion of the variance (Hair et al., 2017). All values in this study exceed the recommended thresholds, thereby confirming the convergent validity of the constructs, as detailed in Table 2.

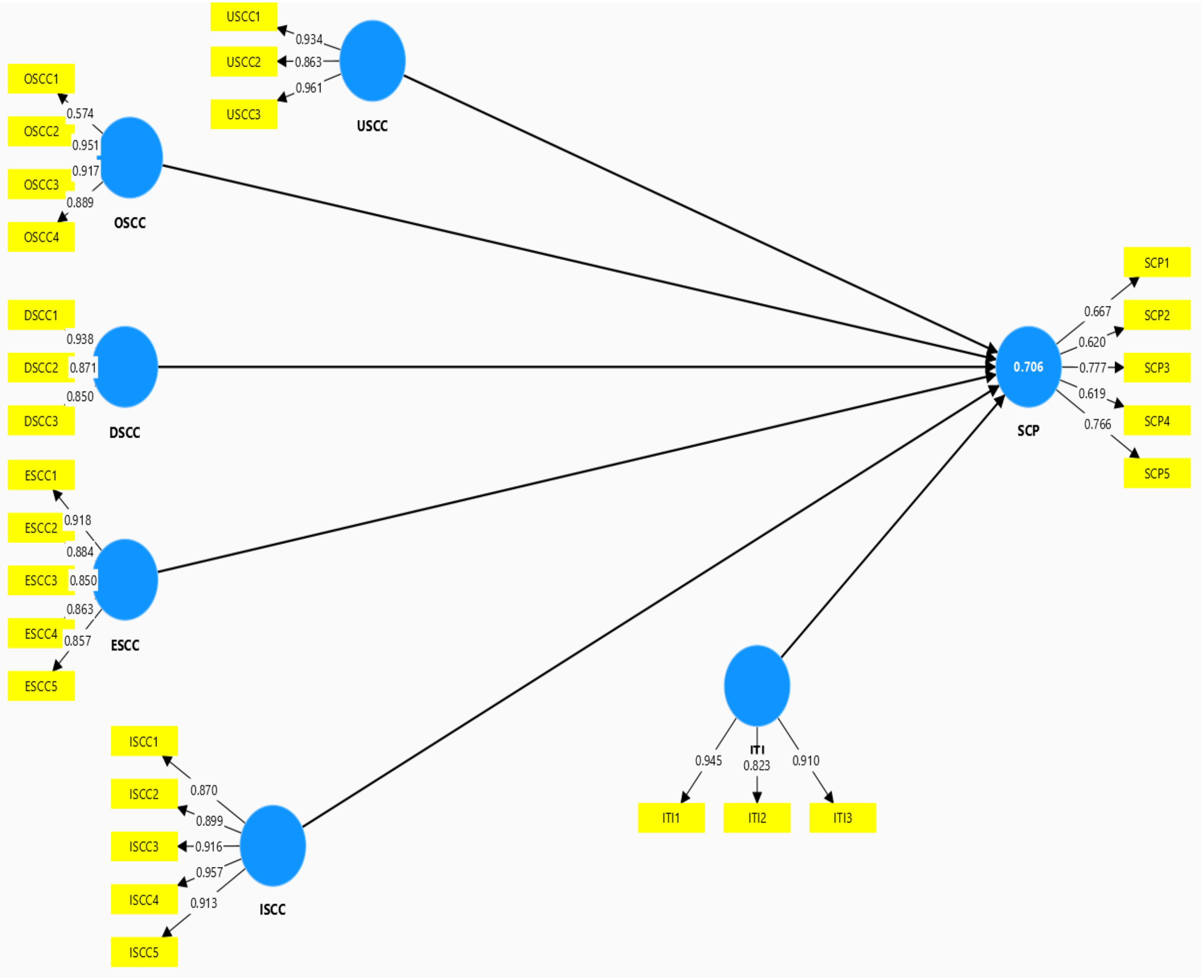

Figure 2: Factor Loadings

Table 2: Convergent Validity

Construct and Indicators	Loadings	AVE	CR
Upstream Supply Chain Complexity			
USCS1	0.934	0.75	0.92
USC2	0.863		
USC3	0.961		
Operations Supply Chain Complexity			
OSCC1	0.574	0.68	0.85
OSC2C	0.951		
OSCC3	0.917		
OSCC4	0.889		
Downstream Supply Chain Complexity			
DSCC1	0.938	0.72	0.88
DSCC2	0.871		
DSCC3	0.850		
External Supply Chain Complexity			
ESCC1	0.918	0.69	0.85
ESCC2	0.884		
ESCC3	0.854		
ESCC4	0.863		
ESCC5	0.857		
Internal Supply Chain Complexity			
ISCC1	0.870	0.74	0.89
ISCC2	0.899		
ISCC3	0.916		
ISCC4	0.957		
ISCC5	0.913		
Information Technology Infrastructure			
ITI	0.945	0.81	0.94
ITI2	0.823		
ITI3	0.910		
Supply Chain Performance			
SCP1	0.667	0.83	0.93
SCP2	0.620		
SCP3	0.777		
SCP4	0.619		
SCP5	0.765		

Discriminant Validity

Discriminant validity is crucial for ensuring that the measured constructs are distinct from each other rather than merely correlated. In PLS-SEM, this validity is assessed using several criteria: Fornell-Larcker criterion, cross loadings, and the Heterotrait-Monotrait Ratio (HTMT). The Fornell-Larcker criterion checks whether the square root of the AVE for each construct exceeds its correlations with other constructs in the model (Rasoolimanesh, 2022). This criterion suggests that a construct should explain more variance in its own indicators than in those of other constructs. Typically, the correlations between a construct and other constructs should be lower than its AVE to fulfil this requirement. Cross loadings evaluate how items intended to measure one construct load more heavily on that construct compared to others. Lower cross loadings indicate better discriminant validity, as items are more clearly associated with their intended constructs rather than with unrelated ones (Rasoolimanesh, 2022). The HTMT ratio compares the correlations between different constructs to those within the same construct, with a commonly used threshold of 0.85. This ratio suggests that the correlation between different constructs should be significantly lower than the correlation within the same construct to establish discriminant validity (Henseler et al., 2015). Furthermore, multicollinearity values below 0.5 confirm that there are no issues with collinearity (Hair et al., 2017). The results shown in Table 3 indicate that the constructs meet the criteria for discriminant validity.

Table 3: Discriminant Validity

Constructs	USCS	OSCC	DSCC	ESCC	ISCC	ITI	SCP
USCS	1						
OSCC	0.352	1					
DSCC	0.531	0.583	1				
ESCC	0.598	0.446	0.359	1			
ISCC	0.452	0.692	0.688	0.436	1		
ITI	0.601	0.233	0.511	0.489	0.321	1	
SCP	0.536	0.448	0.334	0.322	0.445	0.604	1

Hypothesis Results

The next phase of the analysis involved testing the study hypotheses using the structural model. For this purpose, a bootstrap resampling technique with 5,000 iterations was employed. The results indicate that USCC has a significant and positive impact on SCP, thereby supporting Hypothesis H1. Similarly, OSCC significantly and positively affects SCP, supporting Hypothesis H2. DSCC also demonstrates a significant and positive influence on SCP, confirming Hypothesis H3. ISCC is found to have a significant and positive effect on SCP, thus supporting Hypothesis H5. Moreover, the moderating effects of ITI were examined. The results show that USCC positively influences SCP with the moderating effect of ITI, supporting Hypothesis H6. OSCC also positively affects SCP with ITI as a moderator, validating Hypothesis H7. Likewise, DSCC positively impacts SCP with ITI moderating this relationship, thereby supporting Hypothesis H8. Furthermore, ISCC positively influences SCP with the moderating effect of ITI, confirming Hypothesis H10. The direct and moderating effects of these relationships are summarized in Table 4.

Table 4: Hypothesis Results

Hypothesis	Coefficients	Standard Errors	T-Statistic	Decision
H1: USCC->SCP	0.521	0.120	4.331	Supported
H2:OSCC->SCP	0.372	0.123	3.024	Supported
H3:DSCC->SCP	0.452	0.111	4.073	Supported
H4:ESCC->SCP	0.281	0.093	3.121	Supported
H5:ISCC->SCP	0.361	0.121	3.623	Supported
H6: USCC*ITI->SCP	0.612	0.141	4.340	Supported
H7: OSCC*ITI ->SCP	0.293	0.080	3.662	Supported
H8: DSCC*ITI ->SCP	0.294	0.070	4.121	Supported
H9: ESCC*ITI ->SCP	0.353	0.092	3.193	Supported
H10: ISCC*ITI ->SCP	0.222	0.061	3.631	Supported

Measurement Model

The measurement model was evaluated using PLS-SEM with Smart PLS software. To assess the measurement model, both convergent validity and discriminant validity were employed.

DISCUSSION

The research aimed to examine the impact of supply chain complexities on the performance of manufacturing companies in Saudi Arabia, with a focus on the moderating effect of information technology infrastructure. Data were collected from employees within these manufacturing companies using a quantitative research approach. The results from PLS-SEM revealed that upstream supply chain complexity has a significant and positive influence on supply chain performance. This suggests that effective management of upstream complexities is critical for enhancing supply chain performance, which is essential for maintaining a competitive edge in global markets. These findings align with previous studies by Alahmad (2021) and Chand et al. (2022), which highlighted the importance of supplier relationship management in mitigating risks and improving supply chain performance. In the context of Saudi Arabia, where manufacturing companies heavily rely on imported materials, addressing upstream complexities is crucial for ensuring an uninterrupted supply and reducing dependency on unstable global markets. Additionally, the study found a positive and significant impact of operational supply chain complexities on supply chain performance. This result underscores the importance of managing operational supply chain complexities to boost performance in Saudi Arabian manufacturing companies. The findings are consistent with those of Mirmigkos (2020) and Chand et al. (2022), who emphasized the role of optimizing operations to achieve competitive advantages. Thus, effective management of these complexities is essential for Saudi manufacturers to meet market demands efficiently, potentially enhancing their growth in both national and international markets.

In a similar vein, downstream supply chain complexities also exhibit a positive and significant influence on the supply chain performance of manufacturing companies in Saudi Arabia. These results suggest that effective management of downstream processes, such as demand forecasting accuracy and customer service, plays a crucial role in enhancing supply chain performance. This finding is consistent with the studies by Bennett (2024) and Chand et al. (2022), which underscore the benefits of efficient distribution and customer-centric strategies for improving supply chains. The empirical evidence indicates that Saudi Arabian manufacturing companies should focus on optimizing downstream processes to boost supply chain responsiveness and enhance their competitive advantage. Furthermore, external supply chain complexities also demonstrate a positive and significant impact on supply chain performance within Saudi Arabia. This indicates that managing external factors such as market volatility and regulatory compliance positively influences the performance of Saudi Arabian manufacturing sectors. These findings align with the research conducted by Azmi et al. (2022) and Alsakhnini and Almoaiad (2024), which highlight the importance of adaptive supply chain practices in enhancing performance. Addressing these external complexities through strategic planning and resilience-building initiatives is essential for improving supply chain performance. Conversely, internal supply chain complexities also show a positive and significant impact on supply chain performance in Saudi Arabia. The results suggest that managing internal complexities, including operational coordination, process efficiency, and organizational productivity, significantly contributes to enhancing supply chain performance. This finding is supported by the studies of Chand et al. (2022) and Bozarth et al. (2009), which emphasize the role of internal supply chain complexities in boosting performance. Consequently, it is argued that addressing internal complexities can foster innovation and productivity, thereby reinforcing Saudi Arabia's position in global markets and improving its industrial supply chain performance.

The results of the moderating effects analysis revealed that information technology infrastructure significantly moderates the relationship between upstream supply chain complexities and supply chain performance in Saudi Arabia. These findings suggest that, in a context where upstream supply chain disruptions can adversely affect manufacturing continuity, leveraging IT infrastructure is crucial for managing such challenges. Enhanced supply chain visibility and real-time data analytics provided by advanced IT systems facilitate proactive decision-making, ensuring timely availability of raw materials and reducing production downtime. This aligns with Baqleh and Alateeq (2023), who emphasized the significant moderating role of information technology in optimizing upstream processes and improving supply chain performance. Additionally, the moderating effect of information technology infrastructure was also evident in the relationship between operational supply chain complexities and supply chain performance. The results indicate that advanced IT systems help Saudi Arabian manufacturing companies streamline production processes, enhance quality control, and optimize resource allocation, thereby boosting supply chain performance. This is consistent with Yuan et al. (2024), who highlighted the role of information integration in improving operational supply chain performance within the Saudi manufacturing sector. Their research underscores the transformative impact of technology in achieving competitive advantages and enhancing overall supply chain performance.

Information technology infrastructure in Saudi Arabia also significantly moderates the relationship between downstream supply chain complexities and supply chain performance. The findings suggest that IT plays a crucial role in mitigating downstream complexities by facilitating accurate demand forecasting, efficient inventory management, and responsive customer service. These factors are essential for meeting market demands and enhancing overall supply chain performance. This result aligns with Yuan et al. (2024), who demonstrated the moderating effect of information technology on downstream complexities. Their study highlighted the strategic advantages of technology integration in improving order fulfilment and performance. In the context of Saudi Arabia, where customer-centric strategies and supply chain responsiveness are critical for business success, leveraging IT infrastructure is key to addressing supply chain complexities effectively. By enhancing IT capabilities, Saudi manufacturers can better manage downstream complexities, thereby improving supply chain performance. Additionally, the moderating effect of information technology was observed in the relationship between external supply chain complexities and supply chain performance. The results indicate that, in Saudi Arabia, where geopolitical uncertainties and global economic dynamics impact business operations, IT infrastructure is vital for managing external complexities. Real-time data analytics and digital platforms enable manufacturers to navigate regulatory challenges and optimize supply chain operations efficiently. These findings are consistent with Yuan et al. (2024), who also emphasized how IT infrastructure enhances performance amidst external disruptions. Their research underscores the strategic benefits of technology adoption in mitigating risks and ensuring business continuity. Overall, these studies suggest that collaborative IT platforms play a significant role in improving supply chain complexities and driving performance enhancements. The findings emphasize the strategic advantages of integrating advanced technology to support supply chain collaboration and resilience.

Implications

Theoretically, this study offers several significant contributions. Firstly, while prior research predominantly focused on three components of supply chain complexities, there has been limited attention to external and internal supply chain complexities in relation to supply chain performance. This study expands the model by incorporating five dimensions as exogenous variables, thereby providing a more comprehensive understanding of how these complexities impact performance. Secondly, previous studies have largely concentrated on contexts outside Saudi Arabia and on sectors other than manufacturing. By focusing specifically on Saudi Arabian manufacturing companies, this research introduces valuable insights into a relatively underexplored area, offering a new avenue for future research. Thirdly, the study sheds light on the moderating role of information technology infrastructure in the relationship between supply chain complexities and supply chain performance. While earlier research has primarily examined direct effects, this study highlights how IT infrastructure can significantly influence the impact of supply chain complexities on performance. This finding underscores the importance of considering collaborative dynamics and technological infrastructure in theoretical models, thereby providing a more nuanced perspective on how these factors collectively shape supply chain performance. Overall, the research framework developed in this study can serve as a foundation for future research, offering a robust model that other scholars can build upon to further explore the interactions between supply chain complexities, IT infrastructure, and performance.

The study offers several practical implications for both practitioners and policymakers. Firstly, it highlights the critical need for investment in advanced information technology infrastructure to enhance supply chain performance. Practitioners should recognize that IT infrastructure not only addresses direct complexities but also plays a vital mediating role in improving overall performance. Therefore, organizations are encouraged to prioritize the development and implementation of robust IT systems to optimize their supply chain operations. Secondly, the findings emphasize the importance of strengthening collaborative relationships within supply chains. By leveraging IT investments and fostering collaboration, companies can effectively manage supply chain challenges and enhance performance, thereby gaining a competitive advantage. Finally, the results provide valuable insights for policymakers in crafting policies aimed at improving supply chain performance. Effective management of complex supply chain processes through strategic IT investments and collaborative practices can inform policy development and drive improvements in national supply chain performance.

Future Directions

The study has limitations that future research should address. Firstly, the research was confined to manufacturing companies in Saudi Arabia, which may limit the generalizability of the findings to other countries. Future studies could explore similar research in different developed countries to understand how variations in work culture and business environments might influence the results, given that these countries have different operational contexts compared to Gulf countries. Secondly, the study focused on five specific dimensions of supply chain complexities. Future research could consider additional dimensions to enhance the predictive power and comprehensiveness of the findings, thereby providing a more detailed understanding of supply chain complexities. Lastly, the study employed a quantitative research approach with data collected via survey instruments. Future research might incorporate secondary quantitative data or mixed method approaches to explore whether the findings remain consistent across different data sources and methodologies. This approach could offer a broader perspective and validate the results further.

CONCLUSION

The study examined the impact of supply chain complexities on the performance of Saudi manufacturing companies, focusing on the mediating effect of IT infrastructure and the moderating effect of supply chain collaboration. Utilizing a cross-sectional research design, quantitative data was collected from employees within these manufacturing companies. Descriptive and inferential analyses were conducted using SPSS and Smart PLS software. The findings reveal that upstream, operational, downstream, external, and internal supply chain complexities all have positive and significant impacts on supply chain performance. Additionally, the study found that information technology infrastructure partially mediates these relationships, underscoring its role in enhancing supply chain processes amidst these complexities. Furthermore, supply chain collaboration was identified as a significant moderator, amplifying the effect of IT infrastructure on performance and highlighting the importance of collaborative practices in optimizing technological advancements. Theoretical contributions of this study include a deeper understanding of how technological and collaborative factors interact within supply chain management. Practically, the results emphasize the importance for manufacturing firms to invest in robust IT systems and develop strong collaborative relationships to improve performance and achieve a competitive advantage. Future research could build on these findings by exploring different geographical contexts and incorporating additional dimensions of supply chain complexities to assess variations in results.

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APPENDIX

Survey instrument

Upstream Supply Chain Complexity

1. Our firm manages and controls the total number of direct suppliers.
2. Our firm manages multiple tiers of suppliers.
3. Our suppliers are geographically widespread.

Operational Supply Chain Complexity

1. The management emphasizes on restricting the total types of parts.
2. The management encourages to maintain required product variety.
3. The management recommends standardized processes.
4. Our firm manages product life cycle efficiently.

Downstream Supply Chain Complexity

1. Our firm is adept in managing increased number of customer orders.
2. Our firm accommodates the variety of customer specific product features.
3. The management is committed in executing orders variability from customers.

External Supply Chain Complexity

1. The management acknowledges the uncertainty in the market as a potential disruptor to supply chain.
2. The management recognizes technological disruption can impact internal and external supply chain.

Internal Supply Chain Complexity

1. Our organizational structure complicates the coordination and management of our supply chain.
2. The number of steps and procedures in our supply chain processes increases its complexity.
3. Integrating different technology systems within our supply chain adds to its overall complexity.
4. Managing multiple suppliers and their varying lead times creates additional complexity in our supply chain.
5. Fluctuations in customer demand contribute significantly to the complexity of our supply chain operations.

Supply Chain Performance

1. Our company supply chain is able to handle nonstandard orders.

2. Our company supply chain is able to meet special customer specification requirements.
3. Our company supply chain is able to produce products characterized by numerous features options, sizes and colours.
4. Our company supply chain is able to rapidly adjust capacity so as to accelerate or decelerate production in response to changes in customer demand.
5. Our company supply chain is able to rapidly introduce large numbers of product improvements/variation.

Information Technology Infrastructure

1. Software application of ready to serve the objectives of the company and the beneficiary.
2. Software application of ready to ensures reducing time complete the work and the exchange of information.
3. Software application of ready to serve the possibility of adjustments and helps to keep pace with technological developments.