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# Integrating Smart Supply Chain with Green Practices to Enhance Sustainable Supply Chain Performance

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## ABSTRACT

**This study focuses on how Smart Supply Chain (SSC) contributes to enhancing Sustainable Supply Chain performance (SSCP) in the context of multinational enterprises (MNEs) in the Gulf Cooperation Council (GCC) countries and examines whether the relationship is mediated by Green Supply Chain Management (GSCM) practices. This analysis is based on an empirical study involving 302 completed questionnaires collected from multinational enterprises in the logistics and supply chain management sector. The results reveal no direct effects of SSC on SSCP. Furthermore, SSC influences external and internal GSCM practices, and institutional pressures moderate the relationship. Likewise, external and internal GSCM practices significantly influence SSCP. Nevertheless, although a significant direct effect of SSC on SSCP is not found, GSCM indirectly affects SSCP through internal GSCM. The impact of SSC on SSCP is also sequentially mediated through external and internal GSCM practices. Additionally, the study reveals that internal GSCM is the most prioritized factor, followed by institutional pressure when using the ANN approach. The findings reveal important implications for stakeholders. They provide rational arguments that should motivate MNEs in the GCC region. In an emerging context, MNEs can leverage the recommendations from this study to enhance their sustainable supply chain performance.**

**Keywords:** *ANN approach, GCC, institutional pressures, internal and external GSCM, MNEs, smart supply chain, sustainable supply chain performance*

## 1. INTRODUCTION

Supply chain management (SCM), a systematic strategy for managing asset flows from sourcing raw materials, product manufacturing, and delivery to end customers, greatly impacts supply network participants' business goals (Zhang *et al.*, 2023). COVID-19 chaos showed the significance of supply chain flexibility and resilience. Thus, manufacturers and other stakeholders should build resilient and smart supply chains, which is challenging. New ICT technologies like big data analysis, IoT, blockchain, etc., enable smart supply chains (SSC) (Enayati, Gudimetla & Arlikatti, 2024). Technology (push) and market change (pull) drive Industry 4.0, which brings manufacturers closer to customers and provides a new platform for smart production (Lasi *et al.*, 2014). The smart supply chain (SSC) uses modern technologies, especially emerging ICT, to integrate processes across SC partners to establish an intelligent connected system (Zhang *et al.*, 2023; Enayati, Gudimetla & Arlikatti, 2024). Industry 4.0 can incorporate customer needs into manufacturing stages with a cyber-physical system and features horizontal integration throughout the value creation network (Vergara *et al.*, 2023). This value-generation network usually matches supply

chains. Thus, SCM affects smart manufacturing performance in Industry 4.0. Zhang, Tang, & Zhang (2016) stated that smart manufacturing requires smart or smarter supply chains because they affect input availability, production function interaction, finished goods delivery efficiency, and network responsiveness.

Today's supply chain is complex and competitive and is affected by changing market and technology pressures. Firms are pressured to embrace sustainable practices, especially in their supply chains (Basu, 2023). Sustainable supply chains are a strategic imperative driven by multiple compelling considerations, not just a trend (Vergara *et al.*, 2023). First, consumers' sustainable demands are at an all-time high as they are more environmentally conscious than ever (Basu, 2023). This consumers' behavior shift requires firms to shift their supply chains with these values to stay competitive (Ye, Hung Lau, & Teo, 2023). Companies that ignore sustainability risk losing market share to more responsible rivals (Gammelgaard & Nowicka, 2024). Second, regulations worldwide are tightening environmental restrictions to reduce carbon footprints and promote sustainability. Non-compliance can result in severe fines and brand damage, requiring firms to meet legal standards and lead environmental stewardship by integrating sustainability into their supply chains. Third, SCM is cost-effective and helps firms optimize resource consumption and reduce waste to improve operational efficiency. Renewable energy and packaging reduction can save operational expenses and help the environment (Gammelgaard & Nowicka, 2024). This twofold advantage is vital in a competitive market with tight margins. Fourth, Sustainable technology investment fosters creativity (Gammelgaard & Nowicka, 2024). Companies that embrace sustainability frequently find new product development and differentiation opportunities (Ye *et al.*, 2023). Blockchain for sourcing transparency and AI for logistics optimization can improve sustainability and efficiency (Cemberci *et al.*, 2024). A technology edge can distinguish a corporation and promote innovation and responsibility. Fifth, SCM attracts and retains talent, and firms with high sustainability have more motivated and engaged employees, which can boost productivity and reduce attrition. Last but not least, resilience to climate change and resource shortages is increasingly important for business survival. GSCM can help organizations adapt to environmental shocks (Movahed, Movahed, & Nozari, 2024). This diversion in technological resources and GSCM is an ethical and strategic move that improves resilience and competitiveness.

Therefore, we focus on MNEs in the GCC to explore the factors that lead them to achieve sustainable supply chains. GCC represents an emerging and diversifying context that includes Saudi Arabia, UAE, Qatar, Oman, Bahrain, and Kuwait. As oil-dependent nations become sustainable, SSC becomes more important. GCC countries have ambitious sustainability and diversification plans. Saudi Vision 2030 promotes economic diversification and sustainable growth (Chaaben *et al.*, 2024). This study suggests that SSC can improve GSCM and SSCP to promote national goals. This knowledge helps regional MNEs meet local needs and compete.

Recognizing the role is crucial as the GCC diversifies its economies (Chaaben *et al*., 2024). Sustainable firms are more resilient to economic upheavals (Benkhati *et al.*, 2023). This study emphasizes the mediating role of GSCM practices in showing MNEs how to apply smart technologies that improve SSCP. GCC environmental issues include water scarcity, climate change, and sustainable resource management. This study shows how SSC can improve environmental results through GSCM strategies like waste reduction, energy efficiency, and sustainable procurement (Benkhati *et al.*, 2023). These approaches can help regional MNEs meet regulatory requirements and improve their CSR profiles. SSC solutions are ideal for the GCC, which is quickly adopting technology. This study examines how SSC might innovate GSCM techniques for more sustainable operations. The study emphasizes stakeholders' participation in sustainable supply chain processes. Analyzing GSCM mediation shows MNEs how to work with local suppliers, governments, and communities. This participation improves SSCP. MNEs seeking long-term regional ties need such alliances.

Our research contributes to the existing literature by analyzing 302 completed questionnaires from IT and operational managers. First, we show that adopting SSC does not lead to SSCP. However, adopting smart supply chain technologies directly influences internal and external GSCM practices, and the relationship is moderated by institutional pressure, establishing a clear link between technological advancement and sustainable practices in supply chains. Second, we show how adopting SSC leads to sustainability via external and internal GSCM approaches. This way, we provide a novel insight into how technology drives sustainability. Third, the research provides a framework for MNEs to link their supply chain strategy with sustainable practices and attain sustainability targets. Lastly, the study enriches global supply chain management literature by showing how contextual factors like geography and industry variances affect smart supply chain adoption and sustainability in MNEs.

The paper structure is as follows: The next section describes the theoretical framework and development of hypotheses. The next part provides questionnaire development and empirical findings. The next sections provide a discussion, conclusion, and research implications.

# 2. THEORETICAL FRAMEWORK

The study primarily advances GSCM digital transformation theory by examining the impact of the smart supply chain (SSC) on GSCM and SSCP. The study calls this integrative view a Smart GSCM (Nureen *et al*., 2023). The study discusses MNEs' sustainable performance by merging planned and technological digital transformation components of SSC and GSCM from a configurational perspective. GSCM's horizontal configuration is also covered in the study (Kim *et al.*, 2021). Green supplier-customer relations and internal purchasing, production, and packaging processes represent the horizontal configuration (Xu *et al.*, 2023). The theoretical perspective is based on the configurational method (Miller, 1996). Operational and SCM research predominantly uses it (Bag *et al.*, 2020). This theory states that firm structure is determined by organizational subsystem interaction. It can be represented by structure, processes, and strategy, which create organizational configurations (Miller, 1996). Thus, adjusting setup dimensions affects firm performance (Yoshikuni *et al.*,

2024). SCM is complex, with many parties and simultaneous actions. So, the integrative configurational method makes supply chain operations and relations clear (Wang *et al.*, 2023).

Thus, the study examines two configuration levels. SSC setup is considered first via digital transformation. The vertical internal configuration of digital transformation is considered (Plekhanov, Franke, & Netland, 2023). Vertical arrangements imply that organizations will enhance processes by integrating hierarchies (Miller, 1996). We can integrate strategic and operational Smart Supply Chain digital transformation with this perspective. A horizontal external–internal configuration view is used for GSCM analysis. External and internal activities must be linked to improve operations. This approach incorporates external GSCM relationship management with internal supply chain management (Rezaei & Maihami, 2020).

### *2.1 Configuring GSCM Through External–Internal Connections*

Unlike typical SCM research, the study configures GSCM using social and environmental factors to focus on SSCP. GSCM integrates environmental factors into SCM for sustainable production, purchasing, and partner associations (Birkel & Müller, 2024). Green SCM can assist firms in implementing GSCM systems and relate operations management to sustainability (Faggioni, Rossi, & Sestino, 2024). The digital supply chain revolution requires internal and external activities (Lerman *et al.*, 2024); the study integrates I-GSCM and E-GSCM to improve sustainability using theories.

Using configuration theory to increase sustainability, the study links suppliers, consumers, and industrial processes (Saini *et al.*, 2023). Other research examined supply chain elements individually, but this paper configures them horizontally. Integrated internal and external green supply chain activities may help organizations achieve sustainability. Digital transformation requires a clear perspective of external and internal activity. Some GSCM methods include green partnerships (external configuration) and green operations (internal configuration) to improve sustainability (Lerman *et al.,* 2024). The study examines how the digital transformation perspective of smart SCM might help this configurational approach of GSCM create a generic Smart GSCM that improves businesses' sustainability.

### *2.2 Institutional Theory*

Institutional pressure shapes organizations' SSCP, especially GSCM (Marculetiu, Ataseven, & Mackelprang, 2023). Regulations, industry standards, customer expectations, and advocacy groups can cause these pressures. Organizations adopt sustainability standards as stakeholders prioritize them to stay relevant and competitive. These restrictions reduce legal risks and boost a firm's CSR (Agyapong *et al.*, 2023; Ahmed *et al.*, 2020; Bag *et al.*, 2021). Sustainability-focused firms are becoming more popular as environmental awareness grows (Agyapong *et al.*, 2023). Due to this demand shift, green supply chain techniques help organizations achieve customer expectations and stand out in the market. Failing to adapt might cost reputation and market share. Other companies may adopt green supply chain strategies from leading corporations to stay competitive. This ripple effect causes sustainability to spread across sectors. Finally, institutional pressure drives enterprises to adopt green supply chain policies (Agyapong *et al.*, 2023; Ahmed *et al.*, 2020; Bag *et al.*, 2021). Organizations can improve sustainability and environmental stewardship by responding to legislative requirements, consumer preferences, and competitive dynamics. Thus, institutional pressures can serve as moderating factors.

## 3. HYPOTHESES DEVELOPMENT

### *3.1 Direct Effect*

#### *3.1.1 Smart Supply Chain and Sustainable Supply Chain Performance*

The study emphasizes sustainable supply networks. First, the study examines SSC's impact on SSCP from an integrative perspective. Hierarchical layers comprise digital transformation strategy, basic digital technologies, and front-end technologies. These digital transformation initiatives may improve SSCP (Rehman Khan *et al.*, 2022). Digital transformation helps businesses establish new models. These models enable organizations to use the gathered data to position themselves greener in the market. In addition, radical technologies like IoT, cloud, big data, and AI enable data flow and organization, which can improve SSCP (Khan *et al.*, 2022). Some research has focused on this digital dimension, suggesting that Blockchain or cloud systems can improve connectivity and green practices *(Bag et al.*, 2021).

SSCP needs these digital technologies for efficiency, transparency, and accountability (Lerman *et al.*, 2023). Advanced data analytics supported by IoT and Blockchain technology provide real-time supply chain visibility (Dedeoğlu *et al.*, 2020). AI and predictive analytics predict demand and optimize inventories, eliminating overproduction and waste. AI-driven decision-making and risk management help organizations adapt to disruptions and satisfy sustainability goals. Robotics streamlines operations by saving energy and manpower. Due to efficiency and reduced human error, automated warehouses and industrial facilities use less energy and waste (Dedeoğlu *et al.*, 2020; Van Geest, Tekinerdogan, & Catal, 2021). Digital platforms enable material recycling and reuse, product lifecycle extension, and environmental reduction, supporting the circular economy. Technologies improve SSCP by increasing efficiency, reducing environmental impact, and promoting ethics.

MNEs need digital tools to improve SSCP (Ghaderi *et al.*, 2024). These technologies boost MNEs' complex global supply chain efficiency and transparency. MNEs can track materials and products better, reducing waste and encouraging environmental compliance. AI-driven risk staining opportunities can increase supply chain resilience and SSCP (Shan *et al.*, 2023). Automation and robotics improve warehouse and production processes and save energy. Errors are reduced and mitigated via better error detection (Khuan, Shee & See, 2023). Digital tools enhance traceability and responsible sourcing. Digital platforms also promote recycling and reuse, extending product lifecycles and minimizing waste (Ghaderi *et al.*, 2024). Digital advances enable MNEs to integrate sustainability into their supply chains, improving efficiency and the environment. SCC may enable SSCP for MNEs, reducing environmental

impact and improving global social responsibility. Thus, the study presents the following hypothesis to investigate SSC's effect on SSCP empirically:

***H1****: A smart supply chain (SSC) configuration enhances MNEs' sustainable supply chain performance (SSCP) in the GCC context.*

*3.1.2 Smart Supply Chain toward External and Internal Green Supply Chain Management (E-GSCM and I-GSCM)*

SCC is crucial to GSCM (Lerman *et al*., 2024). SSC-GSCM relationships depend on green supply chain configuration. Importantly, external and internal behaviors should reflect environmental goals. According to the configurational approach, digital strategy and technologies cannot provide green performance for the supply chain alone. Aligning E-GSCM with I-GSCM procedures helps achieve goals (Dai *et al.,* 2024). Without their links, firms' activities may be misguided, and optimum advantages may decrease. Organizations must align green alliances, operations, and SSC to achieve sustainability. New digital strategies use front-line technologies like cloud services to communicate data between processes and front-end technologies to improve them (Baines *et al*., 2024). Combined SSC and GSCM can provide firms a competitive edge (Dai *et al.,* 2024). As SSC improves companies employing base technologies, firms using base technologies to collect and analyze data could create new data management and integration options for sustainability. Front-end technology also assists organizations identify green suppliers by increasing green networks. Green operations may help companies negotiate the digital supply chain revolution. Companies can build green digital purchasing by leveraging digital platforms to give new, accurate supplier information and explain how they employ green supply chain processes (Liu *et al.,* 2023). Companies create new green packages with little resources, which IoT sensors can improve to provide to eco-conscious customers.

Combining SSC and GSCM technology transforms sustainability and MNE strategies. SSC improves GSCM externally by increasing supply chain transparency and traceability. IoT sensors and Blockchain technologies help track supply chain emissions, energy consumption, and trash management. MNEs may verify environmental compliance with real-time environmental performance data from these technologies. Firms can verify suppliers' sustainability credentials using Blockchain (Nguyen & Zuidwijk, 2024). Thus, they can track resources and promote sustainability. Transparency builds confidence with environmentally conscious clients and promotes environmental compliance (Nguyen & Zuidwijk, 2024). SSC helps implement circular economy values by improving recycling operations. IoT devices help companies track product lifecycles and methods, which boosts recycling and resource efficiency (Gao *et al.,* 2024). These arguments motivated researchers to test this theory empirically:

***H2a****: A smart supply chain (SSC) configuration is positively associated with higher levels of E-GSCM in MNEs operating in GCC.*

Firms may optimize inventory management and eliminate overproduction and waste through predictive analytics and AI-driven decision-making tools. Firms can precisely estimate demand and modify production to reduce excess inventory and manufacturing and storage environmental impact (De Giovanni, 2021). Automation and robotics streamline warehouse operations (Khuan, Shee & See, 2023). These systems optimize logistics by changing supply pathways and reducing fuel costs. Real-time monitoring by SSC lets organizations manage energy usage across resources, resulting in cost reductions and energy conservation (De Giovanni, 2021). I-GSCM improves internal communication and management, making sustainability points easier to integrate into operations (Buhaya & Metwally, 2024). Thus, enterprises must constantly monitor and improve their environmental performance (Chatzoudes & Chatzoglou, 2022). To improve sustainability, firms combine SSC and I-GSCM. SSC setup helps organizations increase I-GSCM and long-term performance. This hypothesis for empirical inquiry was based on these arguments:

***H2b****: A smart supply chain (SSC) configuration is positively associated with higher levels of I-GSCM in MNEs operating in GCC.*

*3.1.3 External Green Supply Chain Management (I-GSCM) and Internal Green Supply Chain Management (I-GSCM) Relationship*

E-GSCM practices strongly affect internal GSCM practices, enhancing sustainability and operational efficiency. External practices include supplier collaborations, customer interaction, and industry-standard compliance (Lerman *et al*., 2022, 2023). Companies that employ E-GSCM efforts generally improve their internal processes and strategies (Chatzoudes & Chatzoglou, 2022). Setting sustainability benchmarks and performance measurements is an external GSCM activity that affects internal operations. Companies that work with environmentally friendly suppliers examine and improve their internal processes to meet these standards. Their activities might use better sustainable sourcing, waste reduction, or energy efficiency. Working closely with external partners helps organizations integrate insights and best practices into their internal frameworks, enabling continual progress (Chatzoudes & Chatzoglou, 2022).

Additionally, customer demand for sustainable products and practices drives organizations to improve internal GSCM (Chakraborty, Al Amin, & Baldacci, 2023). When clients demand eco-friendly solutions, enterprises adjust their processes. Firms invest in internal GSCM procedures that fulfill customer expectations and environmental goals in response to external market constraints (Chakraborty *et al*., 2023).

E-GSCM practices can spur information sharing and collaboration, improving business capacities. Sharing knowledge, tools, and best practices with supply chain stakeholders helps improve I-GSCM efforts *(*Chakraborty *et al.,* 2023). Firms can adopt creative sustainability solutions using external collaboration insights. In conclusion, E-GSCM practices motivate enterprises to improve their internal sustainability initiatives. Collaboration with suppliers, responsiveness to consumer requests,

responsibility to industry standards, and knowledge sharing can help organizations integrate sustainable practices into their core operations, creating long-term value and environmental stewardship. Thus, we hypothesize as under:

***H3****: External Green Supply Chain Management (E-GSCM) positively influences MNEs' Internal Green Supply Chain Management (I-GSCM) in the GCC region.*

#### *3.1.4 Green Supply Chain Management (I-GSCM and I-GSCM) and SSCP*

GSCM combines environmental issues into supply chain management across and within enterprises (Karmaker *et al.*, 2023). GSCM integrates environmental thinking into supply chain management, encompassing product design, material sourcing and selection, production, consumer delivery, and product life cycle. GSCM helps firms achieve environmental standards. Firm SSCP is affected by GSCM initiatives. GSCM minimizes pollution and enhances sustainable product production (Karmaker *et al.*, 2023).

First, E-GSCM enables companies and suppliers to assess the environmental impacts of product design. Supplier-firm ties increase SSCP (Ghosh, Mandal, & Ray, 2022). Due to the close interaction, firms must build environmentally friendly input logistics with suppliers. Strong firm-supplier relationships help companies understand environmental concerns. Sustainable firms also seek suppliers with product design that affects environmental management systems. The process enhances SSCP (Ghosh, Mandal, & Ray, 2022). Second, E-GSCM allows companies to consult customers on product design and environmental impact. They readily meet environmental compliance criteria and educate clients to boost the firm's image due to strong client ties. Mutual responsibility between firms and customers ensures environmental compliance. Many clients want environmental management solutions for sustainable supply chain management. These activities enhance SSCP. Therefore, we hypothesize as under:

***H4****: An MNE's E-GSCM practices positively impact its SSCP in the GCC context.*

Additionally, I-GSCM strategies improve an MNE SSCP. Eco-friendly practices can boost economic, social, and environmental benefits for companies. Internal GSCM practices, including waste reduction, energy efficiency, and sustainable sourcing, streamline operations and reduce resource consumption. Lean manufacturing reduces material waste and boosts productivity. This reduces costs and supports sustainability (Lerman *et al.*, 2022). Further, promoting sustainability in the workplace encourages eco-friendly behavior. Training and awareness programs can inspire personnel to innovate and green procedures, improving operational performance. Sustainable employees improve continuously, essential for long-term success (Lerman *et al.*, 2022; Stekelorum *et al.*, 2021). Collaboration between procurement, production, and logistics offers a holistic sustainability approach. Cross-functional teams can find and fix supply chain inefficiencies to reduce environmental impact. Integrating suppliers within the sustainability strategy ensures their partners follow green practices, compounding the benefits. Finally, IoT and AI enable real-time supply chain monitoring and optimization (Lerman *et al.*, 2022). These tools let companies track resource usage and emissions for better sustainability decisions. A firm's SSCP depends on its GSCM processes (Lerman *et al*., 2022; Stekelorum *et al.*, 2021). Optimizing processes, creating a sustainability-focused culture, enhancing cooperation, and employing technology can help companies meet regulatory requirements and compete in an eco-conscious market. Therefore, we propose the following hypothesis:

***H5****: An MNE I- GSCM practices positively impact its SSCP in the GCC context.*

## *3.2 Moderation Effect*

Institutional pressures influence the adoption of SSC and internal and external GSCM practices. When firms integrate sustainability into their operations, these forces can help or impede SSC technology and practices (Kalyar, Shoukat, & Shafique, 2020). SSC adoption integrates smart technologies like IoT, AI, and big data analytics into supply chain activities. These technologies improve visibility, efficiency, and reactivity, helping organizations manage resources and reduce environmental impact. Institutional factors often interact the successful adoption of these technologies (Kalyar *et al.*, 2020).

Institutional pressure-mimetic, coercive, and normative-moderates the relationship between smart supply chain (SSC) activities and internal and external green supply chain management (GSCM) practices. Organizations adopt SSC technologies that improve environmental performance under strong pressure to preserve legitimacy. Internal GSCM initiatives like streamlined processes and waste reduction can be enhanced. Regulatory and stakeholder pressure forces corporations to adopt sustainable SSC strategies (Ahmed, Najmi, & Khan, 2020). Firms are more likely to embrace green initiatives to comply with legislation and meet investor expectations, enhancing their external GSCM policies (Lerman *et al.*, 2022, 2023; Gelderman *et al*., 2024). Normative pressure influences organizational behavior based on social and professional ideals (Jazairy & von Haartman, 2020). Strong normative expectations push enterprises to align SSC practices with sustainability goals, boosting supplier engagement and openness. These institutional factors affect how firms deploy SSC technology and the success of their internal and external GSCM activities. Firms seeking sustainability through smart supply chain strategies should comply with these dynamics. Thus, we propose the following hypotheses:

***H6a****: Institutional pressures moderate the impact of SSC on MNEs' E-GSCM practices in the GCC context.*
***H6b****: Institutional pressures moderate the impact of SSC on MNEs' I-GSCM practices in the GCC context.*

## *3.3 Mediation Effect*

#### *3.3.1 E-GSCM as a Mediator between SSC and I-GSCM*

The study outlines the interconnectedness of SSC, E-GSCM, and I-GSCM. The relationships help us to understand how firms align SSC configuration to their E-GSCM and I-GSCM practices (Lerman *et al.*, 2022, 2023). Understanding the relationship better aligns with sustainability strategies and sustainable performance

(Lerman *et al*., 2022). SCM is evolving, and firms are realizing the need for sustainability. This integration is typically seen in GSCM. In the recent past, technological advancement has created SSC with improved data analytics, automation, and real-time monitoring (Ma *et al.*, 2022). SSC greatly affects E-GSCM and I-GSCM practices. SSC configuration improves resource management and efficiency (Ma *et al.*, 2022). Firms track energy use through IoT sensors in real-time, while BDA can find waste reduction potential.

E-GSCM can mediate the impact of SSC on I-GSCM. SSC improves firms' operational efficiency and decision-making with IoT, AI, and big data analytics (Eikelenboom, 2017). Firms with such solutions can monitor external and internal GSCM in real time, use predictive analytics, and coordinate SCM (Susanty *et al.*, 2019). E-GSCM practices, including supplier involvement, customer collaboration, and environmental compliance, help firms establish I-GSCM. SSC helps firms collect and analyze data from external partners and stakeholders (Li *et al*., 2022). Further, it improves communication and collaboration between suppliers and customers, which improves I-GSCM. SSC also helps firms gain insights and encourages GSCM practices, including waste and carbon reductions, through interaction with external partners. SSC in the E-GSCM enhances optimizing I-GSCM policies. Firms can follow GSCM practices via real-time supplier performance data. E-GSCM practices leverage SSC to improve external interactions, endorsing internal I-GSCM practices. So, the study illustrates how the SSC and I-GSCM relationship is mediated via E-GSCM in SCM. So, the following hypothesis is proposed for empirical testing:

***H7****: E-GSCM mediates the relationship between SCC and I-GSCM in MNEs in the GCC region.*

### *3.3.2 GSCM (I-GSCM and E-GSCM) as a Mediator between SSC and SSCP*

SSC configurations and sustainable performance are increasingly important in SCM. SSC configurations use IoT, AI, and Blockchain to improve operational efficiency (Seman *et al.*, 2019). SSC technologies allow real-time data collection, predictive analytics, and supply chain integration. First, the study proposes the direct association between SSC and firms' sustainable performance (SSCP and FP) (Kara & Edinsel, 2023). However, mere SSC configuration does not ensure sustainability. The direct linkages between SSC and sustainable performance need GSCM as a mediator since SSC does not guarantee SSCP (Shahzad *et al.*, 2024). First, SSC may directly influence E-GSCM by using IoT and AI to collect and analyze massive volumes of data from suppliers and customers (Shahzad *et al*., 2024). As a result, the data-driven approach upgrades external stakeholder communication, transparency, and collaboration. Therefore, firms can monitor and manage their suppliers' environmental performance, comply with environmental standards, and collaborate to reduce environmental impact. Improving environmental and operational effects requires recognizing how E-GSCM practices mediate the relationship between SSC configurations and sustainable performance (SSCP and FP) (Singh, 2024). The E-GSCM practices also help firms produce sustainable products that support firms' SSCP. The firms use different mechanisms to improve their SSCP once they apply E-GSCM practices (Singh, 2024). Their relationship with external stakeholders also empowers them to follow sustainable practices. Meanwhile, these firms are marked sustainable in the markets where they operate. They can have a competitive edge over their rivals. They can produce more and charge higher for their sustainable products, and the customers are willing to pay extra. Ultimately, their financial performance improves in the long-run (Agarwal *et al.*, 2018; Susanty *et al.*, 2019). As a mediator, E-GSCM practices significantly affect sustainable supply chain performance. Firms increase sustainability by improving E-GSCM processes with SSC designs. E-GSCM reduces waste, carbon emissions, and resource consumption (Al-Ghwayeen & Abdallah, 2018; Seman *et al.*, 2019). These practices help firms comply with legal and sustainability standards, improving their reputation and FP. So, the study proposes the mediation effect of E-GSCM practices for the association between SSC and sustainable performance (SSCP and FP). These hypotheses are as follows:

***H8a****: E-GSCM mediates the relationship between SSC and MNEs' SSCP in the GCC context.*

In modern SCM, researchers have linked SSC configuration to corporate sustainability. However, the linkages do not provide conclusive evidence. Studies show that SSC's significant impact on firms' sustainable performance and others have no significant association (Wang, Zhang, & Goh, 2018). These contradicting findings may be attributed to the non-inclusion of mediators since SSC may need process development within the organization to maximize the benefits associated with SSC configuration (Susanty *et al.*, 2019). Internal GSCM practices may mediate the relationship. SSC configuration augments procurement, logistics, and production with BDA analytics and advanced technological developments (Li *et al.*, 2022). This complex architecture increases supply chain sensitivity but does not influence corporate sustainability. I-GSCM practices comprising waste reduction, energy efficiency, and sustainable sourcing integrate sustainability into the firm's operations. These resolutions associate SCC configuration with sustainability (Li *et al.*, 2022). Thus, these solutions help firms leverage SSC configuration effectiveness into sustainable performance.

First, the SSC configuration enhances firms' I-GSCM practices (Lerman *et al*., 2022). These enhanced I-GSCM practices are likely to enhance firms' sustainability. The study argues that integrating SSC and I-GSCM practices will likely improve firms' sustainable performance (Lerman *et al.*, 2022, 2023). Firms in the supply chain adopt SSC and use their I-GSCM practices to optimize resource utilization. Further, SSC enables firms to opt for a circular economy that optimizes their resource utilization, which results in better sustainable performance (Kara & Edinsel, 2023).

Hence, I-GSCM practices are expected to mediate SSC configurations' strategic advantages to promote sustainable performance, lower carbon emissions, and increase regulatory compliance. Firms can use SCC to enhance I-GSCM practices, resulting in positive environmental and financial performance. Firms that proactively integrate I-GSCM principles into their SSC frameworks are better placed to achieve sustainable performance (SSCP and FP) (Ibrahim, Aljarah, & Sawaftah, 2021), which may

complement technology innovation and ecological stewardship. Thus, the study proposes the following hypotheses:

***H8b**: I-GSCM mediates the relationship between SSC and MNEs' SSCP in the GCC context.*

*3.3.3 Sequential Mediation Effect*

The study also explores the sequential mediation approach to determine SSC's impact on sustainable performance. The sequential mediation approach helps sustainable supply chain experts grasp complex variable relationships (Ibrahim *et al.*, 2021). This method establishes how one mediator influences another and the output variables (Raza *et al*., 2020). The impact of dependent variables on outcome variables may not be straightforward (Bharadwaj *et al.*, 2022); rather, it needs certain mediators to influence significantly (Raza *et al.*, 2020). Specifically, in supply chain management, the mere application of SSC does not ensure sustainability (Bharadwaj *et al.*, 2022; Khan *et al.*, 2022). The supply chain involves a series of steps to achieve desired goals.

In this sequential mediation approach, the study proposes that SSC configuration impacts firms' E-GSSM practices, which, in turn, influences the I-GSCM practices. This serial influence further led to enhanced SSCP. The approach enables researchers to outline the paths to translate SSC technological advancements in SCM into SSCP. Multiple factors influence the chain where mediation can be most operative (Bharadwaj *et al.*, 2022)This may help researchers understand the mechanisms that play a pivotal role in translating SSC into SSCP and provide insight into how and why certain practices are required to achieve SSCP. In the context of the current study, it is proposed that SSC configuration may positively influence E-GSCM (Lerman *et al.*, 2022), which in turn enhances I-GSCM practices that resultantly increase firms' SSCP (Lerman *et al.*, 2023; Sharma *et al.*, 2024). Through the sequential mediation approach, one can identify leverage points within the sequence where intervening variables may have a significant role to play. First, SSC configuration helps management to build strong relations and affiliations with suppliers and customers. These relationships enhance firms' E-GSCM practices since they can easily adjust through timely data analytics approaches (Lerman *et al.*, 2023, Sharma *et al.*, 2023). Therefore, SSC configuration is expected to influence E-GSCM practices positively. Second, E-GSCM practices further enhance I-GSCM practices. Once a firm has established E-GSCM practices, it can improve its purchasing, manufacturing process, and packaging. The established I-GSCM practices enhance SSCP by optimizing resource utilization (Habib *et al.*, 2021; Novitasari *et al.*, 2023), boosting the circular economy and reducing carbon emissions. Thus, the linkages between SSC and SSCP can be sequentially mediated via E-GSCM and I-GSCM practices. So far, empirics have not provided any sequential mediation effect regarding SSC and SSCP relationships. In the emerging context of GCC, MNEs have the resources and capabilities to adopt a sequential mediation approach to achieve desired objectives. In addition, MNEs have long-term (Zhang *et al.*, 2023). So, they opt for strategic choices that yield long-term sustainable growth. They also have technological developments that may assist them in streamlining the process of achieving SSCP. For instance, realizing that SSC configuration enhances GSCM practices (E-GSCM and I-GSCM), which improves sustainable performance, leads MNEs to focus on strategic choices that augment efficiency and sustainable performance (SSCP and FP). Therefore, the study proposes the following sequential mediation hypothesis following the sequential mediation effect:

***H9**: The relationship between SCC and SSCP is sequentially mediated via MNES' E-GSCM and I-GSCM practices in the GCC context.*

*3.3.4 Research Framework*

**Figure 1** below presents the research framework. It shows that five direct hypotheses and a moderation effect with sub-hypotheses are tested. Three mediation hypotheses and one sequential mediation hypothesis are also included. Control factors include respondent gender, firm size and age, and industry.

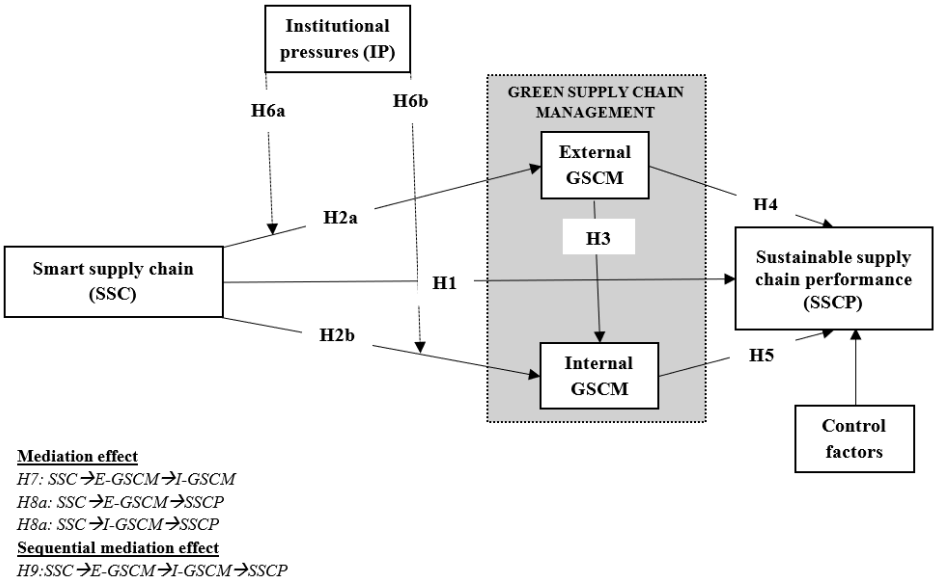


**Figure 1** Proposed research model

# 4. RESEARCH METHODOLOGY

## *4.1 Measures*

This study utilized a comprehensive questionnaire to examine supply chain management constructs, particularly digital transformation and green practices. Our questionnaire is divided into main sections that indicate study objectives-related constructs. The first element covers SSC, which includes Digital Transformation Strategy (5 items), Digital Technology BASE (5 items), and Front-End Technology (4 items) (Shen, Zhang, & Liu, 2022, Lerman *et al.*, 2022). After the SSC, we examine E-GSCM, which comprises Green Supplier and Green Customer Relationships. Four factors assess the Green Supplier Relationship's collaboration and sustainability efforts between firms and suppliers (Saeed *et al.*, 2022). Five Green Customer Relationship construct components examine how firms engage customers on sustainability issues (Saeed *et al.*, 2022; Lerman *et al*., 2022). We then investigate I-GSCM, encompassing Green Packaging, Manufacturing, and Purchasing (Wandosell *et al.*, 2021). The Green Packaging concept has four eco-friendly packaging items. With five items, Green Manufacturing evaluates sustainable production techniques. Four criteria assess the Green Purchasing architecture, showcasing sustainable purchase practices (Wandosell *et al.*, 2021). The questionnaire also assesses institutional pressures, such as coercive, mimetic, and normative. Four items assess coercive pressure from regulations and mandates (Gelderman *et al.*, 2024). Three mimetic pressure questions analyze the inclination to copy successful competitors, whereas three normative pressure items represent industry standards and expectations. Our last dependent variable, SSCP, is assessed using eight elements to assess supply chain sustainability initiatives (Bag *et al*., 2020; Lerman *et al.*, 2022).

Once the questionnaire was constructed, we used a sequential process for its adaptation. In the process, the face validity of the measures chosen for each factor was carried out, wherein nine experts helped refine and clarify each item to avoid any conflict and ambiguity for respondents. In this expert group, three supply chain management academics, three IT managers with at least five years of expertise in MNE, and three supply chain operations managers participated. This varied group of professionals gave a well-rounded perspective on topics like SSC adoption, GSCM, and sustainable supply chain practices. These insights will help us finalize the initial draft.

To ensure relevance and efficacy, 25 MNE-representing firms piloted the draft. Carefully constructed pilot testing involved IT administrators responding to smart supply chain adoption parts. Operational managers addressed GSCM and sustainable supply chain procedures. This specific strategy helped refine how managerial viewpoints affect creative supply chain tactics. To examine pilot test responses, we called another expert group meeting. The pilot respondents' trends, difficulties, and possibilities were identified through this debate. Experts analyzed the data to evaluate each questionnaire item's clarity, relevance, and usefulness. The questionnaire was more comprehensive and usable based on their suggestions and data analysis. The instrument was developed through iteration to represent the intricacies of supply chain management encountered by IT and operations managers.

After finalizing the questionnaire, we briefed each MNE's management on research ethics. We stressed secrecy and assured them that identities and responses would remain anonymous throughout the study. Transparency fostered trust and involvement. To maximize response rates, we followed up systematically after mailing the questionnaire. Each of our four reminders was timed to sustain engagement without overwhelming participants. These reminders boosted the response rate by emphasizing the study's importance and gently encouraging managers to finish the questionnaire.

Despite our efforts, several MNEs did not react or responded incompletely. These issues highlighted the difficulties of conducting research in organizations where competing interests typically overshadow survey participation. Although the response rate may be higher, the data provides interesting insights into IT and operational managers' views on SSC adoption, GSCM, and SSCP. Data was thoroughly analyzed, considering non-responses and partial submissions. The participants' insights will help identify supply chain management trends and difficulties (Cemberci *et al.*, 2024). This rigorous approach underpins the study's significant analysis, and findings based on ethics and proactive communication.

Since our study's unit of analysis is multinational enterprises (MNEs), we reached out to 540 MNEs based in the GCC to participate in our research. For each MNE, we sought responses from two key individuals: the IT or Big Data Analysis Manager and the Operations Manager. The MNEs were selected based on their application of smart supply chain technology. The initial 20.65% response rate was below survey research standards. To increase participation, we devised a disciplined follow-up plan. In the first follow-up, we boosted the response rate by 17.87%, reaching 37.52%. The initial increase showed that our outreach was reaching the targeted MNEs. Encouraged by this progress, we conducted a second follow-up, which increased answers by 14.07%, resulting in an overall response of 51.59%. This gradual development showed that our reminders work, and participant engagement is crucial. Lastly, we hand-collected 58 questionnaires, increasing our overall response rate by 10.74%. After subtracting incomplete responses, we are left with 55.93% response.

The overall response rate was 55.93%, significantly higher than earlier research in this field. The systematic approach to follow-ups reminded respondents of the survey's importance and showed our dedication to their ideas, which increased participation. The final response count provided a strong data collection reflecting GCC MNEs' opinions.

The completed questionnaires enable meaningful analysis and comparison across industries and managerial levels. This response rate lends confidence to our findings and provides a solid platform for studying supply chain management in a region with substantial economic expansion and diversification. The focused engagement with MNEs yielded useful data to help us understand smart supply chain adoption and sustainable practices in the GCC. The descriptions are provided in **Table 1**.

### *4.2 Analyses Procedures*

We used covariance-based structural equation modeling (CB-SEM) and artificial neural networks (ANN) to test our main model. CB-SEM tests the path coefficient and significance level between IV and DV, whereas ANN helped us rank each component based on its importance with DV. The hypothesis was tested, and factor analysis was confirmed using SPSS AMOS V 23. Heterotrait-monotrait ratio of correlations (HTMT) analysis and SPSS full collinearity tests examine common method bias and discriminant validity. Research has used a full collinearity approach to check bias-raw data (Dirgiatmo, 2023). The approach regresses all constructs and generates random numbers (Dirgiatmo, 2023). Further, it produces a dummy dependent variable. To address the technique biases, the value of a comprehensive collinearity test VIF should be below 3.3 (Sakinah *et al.*, 2020). We made multiple iterations for AMOS V.23's weight and structural model. In AMOS, we used Bootstrapping and moderation multi-group analysis (MGA) for the mediation effect. Finally, ANN (AMOS plugin) finds non-linear correlations and ranks crucial constructs.

**Table 1** Data collection

| Methods | IT professional | | Logistics and supply chain managers | | Total | |
|---|---|---|---|---|---|---|
| | N | %age | N | %age | N | %age |
| Emailed | 540 | | 540 | | 1080 | |
| First Response | 107 | 19.81% | 116 | 21.48% | 223 | 20.65% |
| First follow-up | 97 | 17.96% | 96 | 17.78% | 193 | 17.87% |
| Second follow-up | 81 | 15.00% | 71 | 13.148% | 152 | 14.07% |
| personally collected | 58 | 10.74% | 58 | 10.74% | 116 | 10.74% |
| Total | 343 | 63.52% | 341 | 63.15% | 684 | 63.33% |
| Incomplete | 41 | 10.99% | 39 | 11.44% | 80 | 19.88% |
| Complete | 302 | 88.05% | 302 | 88.56% | **604** | |
| **Number of firms (604/2)** | | | | | **302** | |
| Response rate (302/540) | | | | | | **55.93%** |

**Table 2** Respondent and firm profile

| Items | Sub-items | Number | Percentage |
|---|---|---|---|
| Gender | Male | 484 | 80.13% |
| | Female | 120 | 19.87% |
| Qualification | PhD | 08 | 01.32% |
| | Masters | 386 | 63.91% |
| | Bachelors | 210 | 34.76% |
| Experience | 5 years to 10 years | 261 | 43.21% |
| | 10 years to 15 years | 199 | 32.95% |
| | above 15 | 144 | 23.84% |
| Firm size | Small | 96 | 31.79% |
| | Medium | 122 | 40.40% |
| | Large | 86 | 28.48% |
| Firm age | Less than eight years | 51 | 16.89% |
| | Eight to 15 years | 134 | 44.37% |
| | Above 15 years | 119 | 39.40% |
| Sector | Chemical (28, 29) | 39 | 12.91% |
| (HS 2-Digit Classification) | Raw hides, skin, and leather products (41) | 36 | 11.92% |
| | Oil and Gas (42) | 27 | 8.94% |
| | Footwear (64) | 26 | 8.61% |
| | Textiles (50–63) | 26 | 8.61% |
| | Base metals (72–83) | 34 | 11.26% |
| | Machinery and equipment (84) | 31 | 10.26% |
| | Electrical equipment (85) | 25 | 8.28% |
| | Transport equipment (87) | 21 | 6.95% |
| | Agriculture (20-24) | 19 | 6.29% |
| | Others | 18 | 5.96% |

## 5. RESULTS

The study estimates the impact of SSC and GSCM (E-GSCM and I-GSCM) for achieving SSCP among MNEs in the GCC region. In addition, the role of GSCM (E-GSCM and I-GSCM) as mediator and institutional pressures as moderator is also tested. We have studied SSC and GSCM (E-GSCM and I-GSCM), institutional pressures, and SSCP (see **Figure 1**). A proposed model has been empirically tested using 302 respondent data associated with various MNEs in the GCC region. Our findings presented a rich insight into the role of SSC towards achieving SSCP through the mediating role of GSCM (E-GSCM and I-GSCM) and the moderating role of institutional pressures.

## *5.1 Demographics*

The demographic profile of this study's respondents helps interpret the conclusions. Men comprise 78.81% of the sample, while women comprise 22.19%. Males dominate managerial roles, reflecting a regional trend. Most respondents have advanced degrees. Master's degrees are held by 63.91%, bachelor's degrees by 34.76% and Ph.D. degrees by 01.32%. This educational background reflects a well-informed respondent pool with theoretical and practical insights. Most respondents (43.21%) have 5–10 years of job experience. This is followed by moderate experience (10–15 years) (32.95%). This distribution includes both new and experienced experts, providing a variety of perspectives on the study's subjects. Medium-sized enterprises make up 40.40% of the sample. A steady and established market presence is shown by 44.37% of enterprises operating for eight to 15 years, followed by 23.84% of firms above 15. This consistency can reveal how these companies handle conventional and modern supply chain management difficulties. Industry representation is also significant in the sample. The sector representation is led by chemicals, Raw hides, skin, leather products, and base materials respectively. This diversity broadens the data beyond a specific industry, improving generalizability. Demographic features of respondents are balanced enough to support this study's empirical conclusions (see **Table 2**).

## *5.2 Statistical Measures for the Constructs*

We used the item content validity index (ICVI) and the scale content validity index (SCVI). ICVI and SCVI are used to reveal the error-free items in the scale. Our results revealed 0.944 values for ICVI, whereas the SCVI was "1.00," endorsing the content validity of our study. For the construct reliability and validity, we used numerous rounds of analysis, which include Exploratory Factor Analysis (EFA) and Conformity Factor Analysis (CFA). While conducting EFA, we did not consider an item with a loaded value less than 0.30 (Azmi *et al.*, 2020). Our data was normal and free from a higher level of Skewness. Our results show a satisfactory level of the goodness of fit indices (Azmi *et al.*, 2020). ($\frac{\lambda^2}{df} = 1.856, CFI = 0.904, NFI = 0.822, TLI = 0{:}915;\ RMSEA = 0{:}087$). As shown in **Table 3**, the factor loading value is above 0.60. Hence, we retained our variables.

Further, the value for composite reliability is from 0.815 to 0.910, sustaining the measures' reliability (Kaufmann & Gaeckler, 2015). The AVE (average variance extracted) value is above the benchmark of 0.50, implying that our constructs have more explanatory power than error. Construct Reliability (CR) values were above 0.70, indicating the internal consistency and reliability of the measurement models. Discriminant validity was also proved by each latent variable's square root of the AVE being bigger than its correlations with other latent variables. Heterotrait-Monotrait Ratio of Correlations (HTMT) for all latent variables was < 0.90 (Kaufmann & Gaeckler, 2015), confirming discriminant validity. **Table 3** shows the measurement model's validity with convergent and discriminant validity.

**Table 3** Construct validity and discriminant validity

| | CA | AVE | CR | SSC | E-GSCM | I-GSCM | IP | SSCP |
|---|---|---|---|---|---|---|---|---|
| | | | | Fornell–Larcker criterion | | | | |
| SCC | 0.815 | 0.613 | 0.880 | **0.782** | | | | |
| E-GSCM | 0.834 | 0.645 | 0.919 | 0.471 | **0.766** | | | |
| I-GSCM | 0.870 | 0.589 | 0.821 | 0.608 | 0.618 | **0.750** | | |
| IP | 0.829 | 0.640 | 0.936 | 0.622 | 0.648 | 0.564 | **0.773** | |
| SSCP | 0.910 | 0.571 | 0.886 | 0.644 | 0.511 | 0.528 | 0.554 | **0.705** |
| HTMT | | | | SSC | E-GSCM | I-GSCM | IP | SSCP |
| | | | | Heterotrait-Monotrait Ratio of Correlation | | | | |
| SCC | | | | — | | | | |
| E-GSCM | | | | 0.609 | | | | |
| I-GSCM | | | | 0.683 | 0.714 | | | |
| IP | | | | 0.674 | 0.694 | 0.743 | | |
| SSCP | | | | 0.712 | 0.683 | 0.782 | 0.782 | 0.811 |

Note: n=302, CA=Cronbach's alpha, AVE=Average variance extracted, CR= Composite reliability. Diagonal values represent the square root of the AVE of each latent construct. SSC= Smart supply chain, E-GSCM= external GSCM, I-GSCM= internal GSCM, SSCP=sustainable supply chain performance, IP=institutional pressures

## *5.3 Common Method Variance (CMV) and Multicollinearity*

The probability of a significant error in the measures is higher once a researcher uses the same survey network to measure independent and dependent variables (Kitsis & Chen, 2021). There are certain ways to tackle the issue of common method biases (CMB). Primarily, we allow our respondents to answer independently without tempting them to go in a specific direction. They were not shown the model to avoid personal biases when answering the questionnaire. Harmon's single-factor test is used to find factors in all data (Kitsis & Chen, 2021). Overall, 77.28% of the variance was explained by all the factors, and the first factor accounted for 16.70% of the variation, confirming the absence of any single factor in our model and reducing the risk of unexplanatory biases. Further, we assessed VIF to check for any possibility of multi-collinearity among variables, which was observed below 5, confirming the absence of multicollinearity. Lastly, the full collinearity test shows the value of VIF below 3.3, implying that our data is free from the common method bias in the study. Another reason for the absence of CMB may be that we collected data from IT and operational managers, allowing them to answer their relevant questions.

## *5.4 Direct Effect and Moderation Effects*

Once the preliminary tests were performed, we proceeded to hypothesis testing. The results are reported in **Table 4**. The direct impact of SSC on SSCP is statistically insignificant, rejecting H1. Nevertheless, SSC significantly predicts E-GSCM (H2a: β=0.363, p<0.001) and I-GSCM (H2a: β=0.262, p<0.01), supporting H2a and H2b. Thus, SSC does not directly influence SSCP but positively predicts GSCM (E-GSCM and I-GSCM). These results show that SSC adoption has no direct impact on SSCP. In comparison, the impact of SSC on E-GSCM is stronger in terms of coefficient estimates and significance level. Further, E-GSCM also predicts IGSCM (H3: β=0.445, p<0.001), supporting H3. Thus, E-GSCM practices are directly associated with I-GSCM. Next, E-GSCM (H4: β=0.406, p<0.01) and I-GSCM (H5: β=0.552, p<0.001) also predict SSCP, supporting H4 and H5. Thus, our direct hypotheses are accepted except for H1.

We introduced interaction terms between SSC and IP to test the moderation effect. The moderation effect shows that IP significantly moderates the impact of SSC on E-GSCM (H5: β=417, p<0.001) and I-GSCM (H5: β=0.358, p<0.01), supporting H6a and H6b. Though in H6b, the significance level did not change, we observed a significant increase in coefficient estimates, thus supporting our argument. Therefore, institutional pressures influence GSCM practices for MNEs in the GCC region.

The results of the control factors are also provided. Firm size and age are the significant predictors of SSC. For brevity, we show the results of control factors found in sequential mediation effect.

**Table 4** Hypotheses testing

| Hypotheses | B | S/D | t-value | $R^2$ | Results |
|---|---|---|---|---|---|
| H1-- SSC →SSCP | 0.091 | 0.077 | 1.177 | 24.32% | Not accepted |
| H2a--SSC →E-GSCM | 0.363*** | 0.071 | 5.123 | 38.47% | Accepted |
| H2b--SSC→I-GSCM | 0.262** | 0.111 | 2.362 | 35.34% | Accepted |
| H3-E--GSCM →I-GSCM | 0.445*** | 0.073 | 6.062 | 39.08% | Accepted |
| H4-E--GSCM→SSCP | 0.406** | 0.185 | 2.199 | 37.77% | Accepted |
| H5-I--GSCM→SSCP | 0.552*** | 0.126 | 4.367 | 35.15% | Accepted |
| **Moderation effect** | | | | | |
| H6a--SSC*IP →E-GSCM | 0.417*** | 0.065 | 6.372 | 58.22% | Accepted |
| H6b--SSC*IP→I-GSCM | 0.358** | 0.153 | 2.343 | 45.15% | Accepted |
| Control factors | | | | | |
| Gender → SSCP | 0.002 | 0.113 | 1.442 | 74.78% | |
| Firm age → SSCP | 0.211** | 0.113 | 2.321 | 74.78% | |
| Firm size → SSCP | 0.354*** | 0.113 | 4.067 | 74.78% | |
| Managers experience → SSCP | 0.010 | 0.113 | 0.545 | 74.78% | |
| Sector | Yes | | | | |

Note: n=302, SSC= Smart supply chain, E-GSCM= external GSCM, I-GSCM= internal GSCM, SSCP=sustainable supply chain performance. IP=institutional pressures, S/D=standard deviation

## *5.5 Mediation Effect*

We used IBM AMOS V 23 to test the mediation effect of GSCM (E-GSCM and I-GSCM). As Byrne (2009) suggested, the bootstrapping method is conducted to test the indirect effect. We used 2,000 resamples with a 95% confidence interval in IBM AMOS V.23 to conduct the indirect effect of SSC on I-GSCM and E-GSCM (Byrne, 2009).

In H7, we predict the mediation effect of E-GSCM for the association between SSC and I-GSCM. The results are reported in **Table 5**. First, we have already shown that the direct impact of SSC on I-GSCM was statistically significant (H5: β=0.358, p<0.01; see **Table 4**). The impact of SSC on I-GSCM is statistically significant through the mediating effect of E-GSCM (H7: β=0.602, p<0.001), thus supporting H7 and reckoning the partial mediation. In H8a and H8b, we predicted the mediation effect of E-GSCM and I-GSCM for the association between SSC and SSCP. The results infer interesting and useful findings. First, the impact of SSC on SSCP is statistically insignificant through the mediation effect of E-GSCM, rejecting H8a. In contrast, the impact of SSC on SSCP is statistically significant through I-GSCM (H8b: β=0.315, p<0.01), thus supporting H8b and reckoning the full mediation.

Finally, we also tested the sequential mediation effect of E-GSCM and I-GSCM. Our findings show that the impact of SSC on SSCP is sequentially mediated via E-GSCM and I-GSCM (H9: β=0.710, p<0.001), thereby supporting sequential mediation effect and reckoning H9.

**Table 5** Mediation effect

| Hypotheses | B | S/D | t-value | $R^2$ | Results |
|---|---|---|---|---|---|
| H7—SSC→E-GSCM➔ I-GSCM | 0.602*** | 0.077 | 5.637 | 54.64% | Partial mediation |
| H8a—SSC→E-GSCM➔ SSCP | 0.114 | 0.071 | 1.123 | 38.11% | No mediation |
| H8b—SSC→I-GSCM➔ SSCP | 0.315** | 0.111 | 2.654 | 55.09% | Full mediation |
| Serial Mediation Effect | | | | | |
| H9-SSC→E-GSCM➔I-GSCM→ SSCP | 0.710*** | 0.113 | 7.8273 | 74.78% | Full mediation |

Note: n=302, SSC= Smart supply chain, E-GSCM= external GSCM, I-GSCM= internal GSCM, SSCP=sustainable supply chain performance, IP=institutional pressures, S/D=standard deviation

### *5.6 Artificial Neutral Network (ANN)*

Multiple linear regression (MLR) is a popular decision-making tool because of its simplicity and interpretability. MLR lets researchers find and quantify independent variable effects on dependent variables by modeling linear connections. However, linearity dependence can be a drawback, especially in complicated datasets with non-linear connections. Non-linear interactions produce more accurate and robust prediction models than MLR. This is especially important when non-linear influences impact variables' dynamics (Shaker *et al.,* 2020). Due to its black-box nature, ANN cannot test hypotheses (Leong *et al.,* 2020). Thus, the authors used SEM followed by ANN (Asadi *et al.,* 2021; Leong *et al.,* 2020; Mahak *et al.,* 2024). The Root Mean Square Error (RMSE) of training and testing data sets shows model accuracy. Both data sets' standard deviations and averages are also included. **Table 7** provides RMSE and normalized priority values for predictor variables. For training data, the observed prediction accuracy ranges from 0.1277 to 0.1952. The RMSE values are observed in the range of 0.041–0.283 for the testing data. ANN output shows that I-GSCM is the strongest predictor for SSCP, followed by E-GSCM. The relative importance has been derived from the predictor variable importance that is run ten times. The calculation for relative importance is carried out by finding the ratio between the individual and highest importance values. The relative importance shows that I-GSCM is the strongest predictor of SSCP followed by E-GSCM (see **Table 7**).

**Table 7** RMSE values

| ANN | Training Value | Testing value |
|---|---|---|
| Iteration-1 | 0.1604 | **0.283** |
| Iteration-2 | 0.1825 | **0.041** |
| Iteration-3 | 0.1952 | 0.131 |
| Iteration-4 | 0.1709 | 0.063 |
| Iteration-5 | **0.1277** | 0.074 |
| Iteration-6 | 0.1593 | 0.081 |
| Iteration-7 | 0.1794 | 0.058 |
| Iteration-8 | 0.1625 | 0.079 |
| Iteration-9 | 0.1614 | 0.081 |
| Iteration-10 | 0.1477 | 0.076 |
| Average | **0.1647** | **0.097** |
| Standard-deviation | **0.0179** | **0.065** |
| Independent variables ranking | | |
| Independent variables | Normalized importance | Rank |
| SCC | 0.214 | 4 |
| E-GSCM | 0.521 | 2 |
| I-GSCM | **1.000** | **1** |
| IP | 0.465 | 3 |

Note: n=302, SSC= Smart supply chain, E-GSCM= external GSCM, I-GSCM= internal GSCM, SSCP=sustainable supply chain performance, IP=institutional pressures

## 6. DISCUSSION

Our research infers interesting findings. First, we show an insignificant impact of the smart supply chain (SSC) on the sustainable supply chain performance (SSCP) of MNEs in the GCC region. Adopting SSC enhances firms' operational efficiency and data management but does not ensure SSCP. The strategic alignment of sustainable supply chain technology with organizational goals and regional MNE sustainability concerns is crucial to their success. Thus, the SSC needs coordination for sustainability. For a more in-depth view, we opt for GSCM practices. Mere adoption of SCC may yield financial outcomes, but its impact on SSCP may rely on GSCM practices. In line with the argument, SCC positively predicts GSCM practices (E-GSCM and I-GSCM). IoT, big data analytics, and AI improve smart supply chain efficiency, transparency, and sustainability. These solutions promote supplier and customer collaboration, allowing MNEs to monitor and optimize their supply chain network's SSCP. This reduces waste and resource use and meets worldwide sustainability guidelines for MNEs. Intelligent supply chains expedite processes, automate workflows, and enable data-driven decision-making, improving an organization's ability to implement and monitor sustainable practices. MNEs can build a more agile, efficient, and environmentally friendly supply chain.

Further, institutional pressures (IP) moderate the association between SSC and GSCM practices (E-GSCM and I-GSCM) in the GCC. This shows the government's emphasis on sustainability and tightening environmental restrictions. IP forces MNEs to embrace SSC solutions for compliance and sustainability. As the GCC culture and society become more environmentally sensitive, MNEs adopt sustainable practices. To navigate IP, MNEs deliberately link their SSC strategies with local rules and societal needs, thus enhancing their competitiveness and making them GCC sustainability leaders.

We also found E-GSCM practices to be a critical mediator in the relationship between SSC and internal I-GSCM practices. E-GSCM drives MNEs to adopt more stringent internal practices, aligning them with external commitments. Thus, the interaction between external and internal GSCM practices leverages SSC effectively. This mediation highlights the importance of a novel approach to sustainability, where E-GSCM enhances internal practices, ultimately leading to improved SSCP. GSCM (E-GSCM and I-GSCM) practices enhance the SSCP of MNEs in the GCC region. GSCM improves efficiency, waste reduction, and resource conservation by incorporating environmental factors into supply chain activities. The comprehensive approach meets global sustainability standards and rising regulatory demands for ecologically responsible corporate activities. GSCM promotes innovation and sustainable technology development. MNEs can reduce waste by designing products that are easier to recycle or dispose of by focusing on lifecycle assessments and product end-of-life management. We found no significant mediating effect of E-GSCM on the association between SCC and SSCP in the mediation effect. The result may be attributed to the connectedness of external and external GSCM practices, and sustainable benefit can only be achieved through a sequential adoption of GSCM practices. The relations prompted us to test the sequential mediation effect—the result of the sequential mediation effect of E-GSCM and I-GSCM for the association between SSC and SSCP. The finding shows that E-GSCM serves as an initial mediator, augmenting the recognition and execution of sustainability practices among suppliers and customers. E-GSCM advances organizations in implementing sustainable practices by staging cooperation and transparency, which initially prompted firms to improve

internal strategies. Subsequently, I-GSCM becomes a second mediator, translating the knowledge gained from E-GSCM into useful internal practices. This sequential mediation effect highlights the importance of both external and internal practices in leading to SSCP. E-GSCM affects I-GSCM, allowing MNEs to integrate sustainability into their operations and enhance environmental management performance. Thus, MNEs in the GCC region can achieve SSCP by adopting SSC and implementing GSCM practices. The SSC's contribution to SSCP is through the combined influence of E-GSCM and I-GSCM.

# 7. CONCLUSION

In conclusion, our research sheds light on adopting a smart supply chain (SSC) and its effects on SSCP among GCC MNEs. Contrary to our hypotheses, no significant direct link between SSC and SSCP was found. This shows the complexity of sustainability outcomes and the necessity of understanding how technology affects performance measures. Investigating SSC and internal and external green supply chain management (GSCM) methods indicated a significant association. SSC improved these behaviors, proving that smart technologies help MNEs apply sustainable practices. We also observed that institutional pressures moderate this association, suggesting that legislative frameworks and public expectations strongly influence SSC application and GSCM practices. This highlights the relevance of context to the success of the SSC initiative.

Our analysis also showed that external GSCM practices mediate the association between SSC and internal GSCM practices but not the direct effect of SSC on SSCP. While external practices are important for internal capabilities, they may not directly affect sustainable performance. SSC and SSCP were mediated by internal GSCM practices (I-GSCM). Internal strategies and procedures are crucial to transforming SSC adoption into sustainability solutions.

We also showed that SSC impacts SSCP through external and internal GSCM practices using sequential mediation. This sequential relationship shows how MNEs can use SSC to improve sustainability. Our findings indicate that MNEs should integrate internal and external activities supported by smart technologies and institutional forces.

Our research highlights the intricate relationships between SSC, GSCM practices, and sustainability outcomes, adding to the sustainable supply chain management literature. This study suggests that GCC MNEs should nurture internal competencies and external collaborations to improve their sustainable supply chain performance in a competitive and environmentally sensitive market.

# 8. RECOMMENDATIONS

Based on our results on SSC, GSCM, and SSCP in the GCC region, we advocate the following recommendations for MNEs and other firms:

1. MNEs should prioritize developing and improving internal green supply chain management practices. While I-GSCM mediates the interaction between SSC and SSCP, enterprises should train and equip their personnel to execute sustainable practices. This includes encouraging employees to develop and contribute to sustainability projects within a sustainable culture.
2. External GSCM practices do not directly affect SSC on SSCP but significantly improve internal practices. Firms should aggressively seek supplier and customer collaborations to enhance supply chain sustainability. They should set agreed sustainability goals, undertake collaborative training, and create information exchange platforms to ensure external influences favorably impact internal practices.
3. MNEs should understand GCC regulatory frameworks and institutional constraints. By working with local governments and industry associations, companies can learn about changing sustainability requirements and expectations. By adjusting to these constraints, strengthening their GSCM practices, and aligning their strategy with national sustainability goals, companies can improve their supply chain performance.
4. Firms should approach SSC technology implementation holistically. Technological advances must align with internal and external GSCM strategies. The integration of SSC capabilities with current procedures and practices facilitates smooth collaboration between internal teams and external partners. Monitoring and evaluating technology implications on sustainability outcomes can help organizations improve their strategy and results.

Following these recommendations, MNEs and other GCC enterprises can enhance their sustainable supply chain performance through smart supply chain adoption and create a more sustainable business environment

# DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions

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# APPENDIX A: QUESTIONNAIRE

**You are requested to specify by tick (√) the level of importance the following smart supply chain configuration (SSC) best reflects in your firm. (Seven-point scale: 1= Not at all important,2= Slightly important,3= Moderately important,4= Important, 5= Very important, extremely important and 7= Absolutely essential)**

**Digital Transformation Strategy**

We aim to digitalize everything possible in the supply chain.

We aim to collect large amounts of data from different sources in the supply chain.

We aim to create a more robust communication network between different supply chain sectors with digital technologies.

We aim to exchange information in the supply chain with digitalization.

We aim to improve the interface with customers with digitization efficiently.

**Digital Technologies BASE**

We use the Internet of Things in our supply chain processes.

We use cloud computing in our supply chain processes.

We use Big Data Analytics in our company processes and the supply chain.

We use artificial intelligence in supply chain processes.

**Digital Technologies FRONT-END**

We use collaborative robotics in our company processes and the supply chain.

We use computer simulation in supply chain processes.

We use augmented reality in supply chain processes.

We use 3D printing in supply chain processes.

**You are requested to specify by a tick (√) the extent of your company's relationship with the Supplier and customers. (Seven-point scale: 1=Not at all,3=Slightly, 3= Somewhat,4=Moderately,5= Very, 6= Extremely and 7= Absolutely)**

**Green Supplier Relationship**

Our company cooperates with suppliers to consider environmental issues in product design.

Our company develops input logistics with suppliers to be more environmentally friendly.

Our company prefers suppliers that have an environmental management system.

**Green Customer Relationship**

Our company works with customers to consider environmental issues in product design.

Our customers have asked us for information on our environmental compliance.

Our customers have demanded that our company ensure the sustainable practices of our suppliers.

**Green Packaging**

Our company packaging is reusable.

Our company's packaging uses as few materials as possible.

Our company encourages the use of reusable packaging.

Our company promotes packaging recycling and reuses programs.

# APPENDIX A: QUESTIONNAIRE (CONT'D)

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|---|
| **You are requested to specify by a tick (√) the extent of your company's relationship with the Supplier and customers. (Seven-point scale: 1=Not at all,3=Slightly, 3= Somewhat,4=Moderately,5= Very, 6= Extremely and 7= Absolutely)** |
| **Green Manufacturing** |
| Our company assesses the environmental impact of developing/improving products. |
| Our company develops products with recyclable raw materials. |
| Our company develops products with the lowest consumption of resources. |
| Our company develops products with low impact on the environment. |
| Our company develops products with a high lifespan. |
| **Green Purchasing** |
| Our company purchases are based on environmental specifications established by product design. |
| Our purchasing process is carried out with ISO 14001-certified partners. |
| Our purchasing process follows procedures that minimize environmental impact. |
| Our purchasing process follows product labeling standards to minimize environmental impact. |
| **You are requested to specify by a tick (√) the extent to which you agree with the following statements relating to institutional pressure firms face in the industry. (Seven-point scale: 1 =Not at all,2=Very minimally,3=Minimally, 4=Moderately,5= Significantly, 6=Very much and 7=To a great extent)** |
| **Coercive pressure** |
| If a firm in our industry does not meet the legislated standards for pollution control, it faces a significant threat of legal prosecution. |
| Firms in our industry are aware of the fines and penalties potentially associated with environmental irresponsibility. |
| If a firm in our industry commits an environmental violation, the outcome will likely include negative reports by industry/stock market analysts. |
| Firms in our industry face negative consequences if they fail to comply with the federal and provincial environmental laws. |
| **Mimetic pressure** |
| Leading companies in our industry model environmental responsibility. |
| Our industry leaders are known for their environmental practices. |
| Leading companies in our industry reduced their environmental effect. |
| **Normative pressure** |
| Trade associations (or professional associations) in our industry emphasize environmental responsibility. |
| It is anticipated that all firms in our industry demonstrate environmental responsibility. |
| Being environmentally responsible is an obligation for firms to be part of our industry. |
| **By a tick (√), you are requested to specify the degree to which your organization has achieved the following sustainable supply chain performance objectives. (Seven-point scale: 1=Very Low, 2= Low, 3=Somewhat Low, 4= Moderate, 5=Somewhat High, 6= High and 7= Very High)** |
| Our organization has visibility of supply chain dynamics in the network. |
| Our organization manages risks in the supply network proactively. |
| Our organization has proper control over supply chain costs. |
| Wastages in our supply chain network have been reduced significantly. |
| Our organization's supply chain can supply final customers with timely, complete orders. |
| Our organization can adhere to environmental standards as per customer requirements. |
| Our organization has minimized buffer stocks at all levels throughout the supply chain. |
| Our organization's supply chain can respond faster than competitors in a volatile business environment. |

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