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Industry 4.0 Technologies and Firm Performance with Digital Supply Chain Platforms and Supply Chain Capabilities

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Abstract

We used a dynamic resource-based view (DRBV) to examine how Industry 4.0 technologies (I4.0) affect business performance. We also examined whether the relationship between I4.0 and firm performance is sequentially mediated via digital supply chain platforms and supply chain capabilities. We used the PLS-SEM technique to analyze the data. After analyzing data collected from 348 logistics and supply chain managers, we found that adopting I4.0 leads to improved operational performance and digital supply chain platforms (DSCPs). However, I4.0 does not enhance competitive firm performance. DSCPs boost operational and competitive firm performance. Further, supply chain capabilities also boost operational and competitive firm performance. In mediation analyses, DSCPs partially mediate the I4.0 and operational performance relationship. Sequential mediation analyses demonstrate that the I4.0 impact on operational and competitive firm performance is mediated via digital supply chain platforms and supply chain capabilities. Lastly, operational performance boosts competitive performance. The firms should focus on digital supply chain platforms and capabilities, as mere adoption of I4.0 does not lead to competitive performance in the GCC context. The findings of this study have theoretical and practical implications.

Keywords: industry 4.0 technologies, digital supply chain platforms, supply chain capabilities, operational performance, competitive performance, supply chain management, Gulf Cooperation Council economies.

1. Introduction

The core principle of this study is to examine how implementing I4.0 technologies in the Industry increases the firm's performance. I4.0 is a strategic method based on technology that creates a production system or smart factory to manage market changes in industrial settings. So far, its business impacts have attracted study attention in recent years (Han & Trimi, 2022). Interoperability, virtual applications, decentralized systems, real-time capabilities, service orientation, and modular production are its principles (Piprani, Khan, & Yu, 2024). These principles focus on processes, products, and business models (Lopes de Sousa Jabbour, Jabbour, Godinho Filho, & Roubaud, 2018). This empowering technology improves firms' operational efficiency.

The role of digitalization is vital for several reasons. It interlinks the industry process with sustainable development (Lopes de Sousa Jabbour et al., 2018). Manufacturing organizations use I4.0 to address mass personalization, real-time decision-making, and demand uncertainty (Abdullah, Al-Ahmari, & Anwar, 2023). I4.0 can improve operational efficiency, responsiveness, traceability, capacity utilization, and cost, boosting sustainability (Gadekar, Sarkar, & Gadekar, 2022). Data transparency also reduces erroneous deliveries, superfluous material flows, and value chain costs, reducing waste and improving environmental performance. Thus, digitalization technologies connect the physical and virtual worlds, allowing industrial enterprises to boost efficiency.

Though empirics have shown positive results regarding the impact of I4.0 on firm performance (Dobrowolska & Knop, 2020; de Mattos Nascimento et al., 2024; de Oliveira-Dias et al., 2023), the firms involved in the supply chain present a diverse structure where embracing the I4.0 technologies may prove costly, specifically in emerging contexts (de Mattos Nascimento et al., 2024; de Oliveira-Dias et al., 2023). Some researchers contend that adopting I4.0 raises challenges, including change management, labor certification, and business model expiration (Dobrowolska & Knop, 2020). Most research on this topic has been conceptualized (Ardolino, Bacchetti, & Ivanov, 2022). Researchers emphasized the necessity for additional empirical investigations to understand the I4.0 and performance relationship (Ardolino et al., 2022). This study was prompted by Industry 4.0's impact on corporate operations in GCC economies. As the global supply chain evolves, GCC companies must modernize and increase operational efficiency with digital solutions. Industry 4.0 technologies like IoT, AI, big data analytics, and blockchain improve supply chain visibility, agility, and decision-making. In addition, Digital supply chain systems are widely used (de Mattos Nascimento et al., 2024; de Oliveira-Dias et al., 2023), but more is needed to know how they affect GCC performance. This study investigates Industry 4.0, digital supply chain platforms, and firm performance to close that gap. The GCC, a region with rapid digital change and strategic importance in global trade, is used to demonstrate how firms may leverage emerging technology to gain a competitive edge, increase operational efficiency, and grow sustainably.

While empirical studies have been conducted on how I4.0 technologies impact firm performance, there are specific ways in which DSCPs and SCCs mediate the I4.0 and performance relationship. These approaches should demonstrate the fundamental mechanisms connecting I4.0 with firm performance. In addition, the need for more research on the impact of I4.0 on firm performance in logistics and supply chains also contributes to the existing conflicts among researchers. In emerging economies, many firms still need help to integrate I4.0 technologies. However, more research needs to be done on how I4.0-enabling technologies affect firms' operational and competitive performance.

Further, firms in these economies prefer financial targets over marketing goals in digitalization. Cost-related challenges and the absence of policy support hinder corporate digitization (Ardolino et al., 2022).. Therefore, highlighting I4.0 and firm performance relationships in the logistics and supply chain context is critical for emerging economies. We also delved into mediation and sequential mediation effects of digital supply chain platforms (DSCPs) and supply chain capabilities (SCCs), as the dynamic resource-based view (DRBV) suggests that organization dynamic resources play a crucial role in adopting I4.0 and leveraging it with firm performance (Mitkas & Nikolaidou, 2010). DRBV provides insights into how firms can use these technologies effectively.

The study expands knowledge on I4.0 adoption and corporate financial and operational performance. First, we investigated how I4.0 affected the company's operational and competitive performance. The firm often prioritizes its performance over technological adoption. In addition, this study employed the empirical method to apply the dynamic resource-based view (RBV) theoretical framework to clarify the impact of adopting I4.0 on firm performance, the advancement of DSCPs, SCCs, and firm performance. This work presents novel insights into implementing DRBV for future research. This study aims to reveal previously undisclosed information regarding the intricate dynamics between I4.0 and firm performance. We used mediation and sequential mediation approaches to show the path contributing to I4.0 and performance relationships. Our study shows the impact of I4.0 on firm performance. DSCPs and SCCs are used as mediators in mediation and sequential mediation effects. This is a novel approach to exploring the impact of I4.0 on firm performance. Adopting I4.0 may not guarantee firm success as it seems costly in the initial stages, and firms are not likely to adopt it. We show that firms can develop DSCPs and SCCs to take advantage of adopting 14-0. Lastly, the study also contributes to the emerging context. GCC economies have the dynamics of emerging contexts with future technological adoption prospects. The research provides a timely solution to the successful adoption of I4.0.

The remainder of the research is as follows: The next section presents the theoretical framework and development of hypotheses, followed by the construction of a questionnaire and data collection process. Further, methods and empirical findings are presented,

followed by a discussion and sections on research implications and limitations. Appendix A provides the operation definition of each construct used in the current study.

2. Theoretical Framework

The current study uses the DRBV as a theoretical framework. DRBV is a robust theoretical framework. Contrasting the resource-based view that focuses merely on static resources and capabilities, the DRBV underlines the dynamic nature of resources and their capabilities that evolve and adapt over time (Huang, Wang, Lee, & Yeung, 2023). According to DRBV, firms have diverse resources and capabilities, which provide a competitive advantage (de Oliveira-Dias, Maqueira-Marin, Moyano-Fuentes, & Carvalho, 2023). I4.0 offers dynamic resources, including advanced analytics, artificial intelligence, Internet of Things (IoT) devices, and robotics that can be used as a source of competitive edge. I4.0 technologies enable firms to upgrade and reconfigure their dynamic resources in response to market competitiveness and technological advancements (Huang et al., 2023). I4.0 interacts with current firm resources and capabilities, creating synergies (de Oliveira-Dias et al., 2023). Within the context of DRBV, researchers can explore how firms can integrate and organize I4.0 technologies with their existing resources to optimize efficiency, which may lead to operational and competitive performance.

In the current study, I4.0 adoption is used as a metric of technological development that leads to better operational and competitive performance. The digital supply chain platforms and supply chain capabilities are used as firms' capabilities that interact with I4.0 technologies to provide operational efficiency and competitive edge (de Oliveira-Dias et al., 2023; Rashed, Bagum, Kibria, Chowdhury, & Islam, 2024). This study uses the DRBV to examine how DSCPs and SCCs affect I4.0 firm performance. It investigates how a company's IT resources, particularly the implementation of I4.0 and advancements in DSCPs, might be mediated by dynamic capabilities within supply chains (SCC), leading to a competitive advantage in firm performance.

3. Hypotheses Development

3.1. Effect of I4.0 Adoption on Firm Performance

From the DRBV standpoint, I4.0 technologies serve as the firm's means of processing information to facilitate operations and competitive management decision-making. I4.0 is expected to enhance manufacturing enterprises' operations (0P) and CP by information collection and analysis. I4.0 leads to efficient information processing, improving operational efficiency, and increased profits (Kerin & Pham, 2019). In an advanced manufacturing system, companies use the Internet of Things, cloud computing, big data, and analytics to collect and analyze production and operations data. These gadgets share data and communicate in various ways (Zheng, Ardolino, Bacchetti, Perona, & Zanardini, 2020). Zheng et al. (2020) stated that cloud computing allows the storage of operational data remotely through different channels and gives on-demand cloud data storage access. Big data analytics can detect and extract information, enabling manufacturing

organizations to make accurate decisions (Kamble, Gunasekaran, & Dhone, 2020). In summary, the improved ability to process information is the main factor that increases production efficiency and, thus, a competitive advantage (Zheng et al., 2021).

Digital technologies aid demand forecasts, pricing optimization, and product development (Umar, Khan, Yusoff Yusliza, Ali, & Yu, 2022). These technologies enable businesses to meet client requests better, increasing efficiency and competitiveness. Li, Dai, & Cui (2020) corroborate this notion and suggest that I4.0 enhances firm performance. Manufacturing companies use the Internet of Things, cloud computing, big data, and analytics from design to after-sales support (Umar, Khan, Yusoff Yusliza, Ali, & Yu, 2022). Advanced digital technology can provide product and market data for product optimization and demand forecasts to meet customer needs quickly. I4.0 improves operations and competitiveness. The following hypotheses are proposed-

- H1a: I4.0 adoption enhances operational performance in the GCC context.
- H1b: I4.0 adoption enhances competitive performance in the GCC context.

3.2 I4.0 and Digital Supply Chain Platforms (DSCPs)

The DRBV asserts that a company's different resources undergo unique paths of evolution and development (Helfat & Peteraf, 2003; Scuotto, Caputo, Villasalero, & Del Giudice, 2017). The advancement of DSCPs hinges on the ability to adjust and use specific data and digital technologies (Hahn, 2020; Rehman et al. 2024). The intangible advancement of DSCPs relies on the implementation of concrete and up-to-date technology, specifically those utilized in I4.0. To advance in DSCPs, organizations should fully integrate technologies into their operations and embrace them ahead of their competition (de Oliveira-Dias et al., 2023). Therefore, organizations leading the way in adopting or coordinating many advanced technologies of I4.0 may gain a competitive edge over their industry competitors (Dalenogare, Benitez, Ayala, & Frank, 2018), thereby improving their DSCPs. DRBV states that when I4.0 technologies reach a specific scale advantage, firms can utilize these technologies to advance their DSCP beyond the level of I4.0. Therefore, it is argued that adopting I4.0 will lead to the advancement of DSCPs, and the study proposes the following hypothesis.

- H2: The adoption of I4.0 enhances digital supply chain platforms in the GCC context.

3.3 Digital Supply Chain Platforms and Firm Performance

Digital supply platforms (DSCPs) coordinate production, logistics, data management, application software and processes across several organizations (Sedera, Lokuge, Grover, Sarker, & Sarker, 2016). DSCPs combine IoT and supply chain management systems (Sedera et al., 2016). If organizations can use technology and data effectively, DSCPs are

feasible. Since DSCPs allow for differences from competitors, they may improve performance (Hautala-Kankaanpää, 2022).

Furthermore, DSCPs can enhance efficiency, collaboration, visibility, and transparency (Markus & Loebbecke, 2013; Rehman et al. 2024), increasing OP and CP. Additionally, DSCPs help enterprises adapt to shifting markets and consumer preferences. Limited evidence shows the influence of DSCPs on firm performance (Lee et al., 2023). DSCPs additionally provide emerging market enterprises access to innovation and experience. Thus, DSCP enterprises are agile and competitive, improving operations and performance. This study proposed the following hypotheses.

- H3a: digital supply chain platforms enhance a firm's operational performance in the GCC context.
- H3b. digital supply chain platforms enhance a firm's competitive performance in the GCC context.

3.4 Effects of DSCPs on Supply Chain Capabilities (SCCs)

DRBV theory suggests that the advancement of DSCPs can be a first-mover advantage for enterprises, enabling them to develop SCCs. The firm's high level of DSCP's progress signifies its possession of sophisticated IT resources, which enable faster communication and reduced transaction costs with supply chain partners compared to its competitors (Mikalef, Krogstie, Pappas, & Pavlou, 2020). DSCPs enhance visibility, collaboration, and agility, which influence SCCs. These platforms improve communication and collaboration, resulting in better stakeholder coordination. DSCPs predict based on their analytics and automation, allowing firms to adapt to market changes. Further, DSCP improvements speed up and improve information acquisition and exchange, ensuring that essential information is available and supplied quickly to all supply chain partners (Tigga et al., 2021). A visual platform for information exchange with a low risk of unauthorized disclosure and high dependability can improve information sharing and supply chain responsiveness (Huang et al., 2023; Nagariya, Mukherjee, Baral, & Chittipaka, 2023). Enterprises can instantly address any change or issue, improving supply chain cooperation. The study proposed that-

- H4: digital supply chain platforms enhance supply chain capabilities.

3.5 Supply Chain Capabilities (SCCs) and Firm Performance (OP and CP)

Existing research suggests a direct relation between SCCs and an organization's performance. According to the DRBV, developing unique SCCs through integrating supply chain processes allows supply chain partners to gain a competitive edge (Ellinger et al., 2011). SCCs increase sales and market share by delivering customers faster. They also let suppliers and customers into operational and distribution-challenged markets (Kovács, Tatham, & Larson, 2012). SCCs help downstream supply chain partners efficiently meet consumer needs (Gawankar, Kamble, & Raut, 2016), hence enhancing OP. Previous studies have revealed a direct association between the flexibility of a supply chain to adapt

to shifts and its operational effectiveness (Wang, Han, Kang, Wan, & Ju, 2022). Supply chain coordination, dynamic capacities, and information sharing enhance the dimensions of CP at the organizational level (Hong, Liao, Zhang, & Yu, 2019). Consistent with the existing body of research, the following hypotheses were proposed:

- H5a: Supply chain capabilities enhance firms' operational performance in the GCC context.
- H5b: Supply chain capabilities enhance firms' competitive performance in the GCC context.

3.6 Operational Performance (OP) and Competitive Performance (CP)

OP refers to how efficiently and effectively a firm uses its internal processes to achieve its goals. The process entails enhancing crucial performance metrics, including productivity, quality, and cost-effectiveness (Mikalef et al., 2020). OP can raise a competitive edge since it minimizes expenses and augments consumer contentment by assessing and enhancing operational efficiency. Due to various factors, operational effectiveness is essential for firms (Mikalef et al., 2020). Primarily, it can substantially affect a company's CP. Improving OP can enable a corporation to augment its income, save expenses, and enhance compatibility (Inman, Sale, Green Jr, & Whitten, 2011). Ensuring efficient OP is crucial for sustaining a competitive advantage. Organizations must consistently enhance their efficiency and effectiveness in the dynamic business landscape to maintain a competitive edge over their rivals (Mikalef & Pateli, 2017; Wong, Boon-Itt, & Wong, 2011). Consistent with the existing body of research, this study proposes the following hypotheses:

- H6: Operational performance enhances firms' competitive performance in the GCC context.

3.7 The Mediating Role of Digital Supply Chain Platforms (DSCPs)

DSCPs frequently connect I4.0 to firm operational and competitive performance (Govindan, Jain, Singh, & Mishra, 2024). These platforms enable organizations to integrate the supply chain ecosystem using IoT, big data analytics, AI, and Blockchain. They enhance automated decision-making with real-time visibility and predictions. DSCPs optimize workflows to boost business efficiency (Govindan et al., 2024). They provide data-driven inventory management and operations insights. They improve agility and responsiveness by enabling stakeholder collaboration and information sharing. Thus, DSCPs may increase I4.0's operational impact on enterprises.

Competitively, DSCPs have various benefits. The adoption of I4.0 affects DSCPs. I4.0 and DSCP integration improves customer service, time-to-market, and product quality (Govindan et al., 2024; Kim, Park, & Jeong, 2020). They optimize supply chain processes, reducing costs and giving enterprises a pricing advantage. Similarly, (Lin, Wu, & Song, 2023) found that implementing DSCPs allows a company to synchronize supply and

demand effectively, promptly respond to consumer requirements, and ultimately increase its sales volume. Molinaro, Danese, Romano, & Swink (2022) propose that adopting information and communication technology-based supply chain platforms reduces costs. Qrunfleh & Tarafdar (2014) demonstrate that adopting DSCPs affects a firm's operational efficiency. Their study suggests that DSCPs facilitate I4.0's effects on OP and CP. I4.0 technology helps the company process information and make quick judgments. Thus, this study hypothesizes the following:

- H7a: Digital supply chain platforms mediate the relationship between I4.0 and firms' operational performance in the GCC context.
- H7b: Digital supply chain platforms mediate the relationship between I4.0 and firms' competitive performance in the GCC context.

3.8 Digital Supply Chain Platforms (DCPs) and Supply Chain Capabilities (Sequential Mediation)

The relationship between I4.0 and firm performance is complex as it relies on different platforms and resources (Messeni Petruzzelli, Murgia, & Parmentola, 2022). I4.0 improves performance by establishing DSCPs and SCCs. A company's productivity and performance can improve with DSCPs and SCCs. It is essential to recognize that I4.0 adoption may not maximize performance benefits (Belhadi, Kamble, Gunasekaran, & Mani, 2022; Messeni Petruzzelli et al., 2022; Rehman et al. 2024). Though I4.0 adoption offers a reliable foundation for integrating distinct incentives to enhance the association between I4.0 and firm performance, it is crucial to acknowledge that not all companies can acquire platforms and capabilities from resources that subsequently improve their performance (Eslami, Jafari, Achtenhagen, Carlbäck, & Wong, 2024). This aligns with the DRBV, which states that firms vary in resources, determining their market competitiveness (Belhadi et al., 2022; Nayal et al., 2022). More resource-rich firms will likely realize more significant improvements in operations and CP from these networks (Karmaker, Al Aziz, Ahmed, Misbauddin, & Moktadir, 2023). Thus, SDCP and SCCs will sequentially mediate I4.0's favorable impact on firm performance (OP and CP). From the dispute, the study presents the following hypotheses:

- H8a: Digital supply chain platforms and supply chain capabilities sequentially mediate the positive effect of I4.0 on operational performance.
- H8b: Digital supply chain platforms and supply chain capabilities sequentially mediate the positive effect of I4.0 on competitive performance.

4. Methods

4.1 Research Framework

Thus, using DRBV, the study constructs and examines a conceptual model (Figure 1) linking I4.0, DSCPs, SCCs, and firm performance (OP and CP). The framework includes direct and mediation hypotheses for empirical analyses. First, the direct association

between the independent and dependent variables is empirically tested. For this purpose, nine direct hypotheses are constructed to test the association between IV and DV (including three sub-hypotheses). Four indirect hypotheses have been proposed to address the model, including H7 (a and b) and H8 (a and b), for mediation and sequential mediation effect. The study also includes several control factors (see Figure 1).

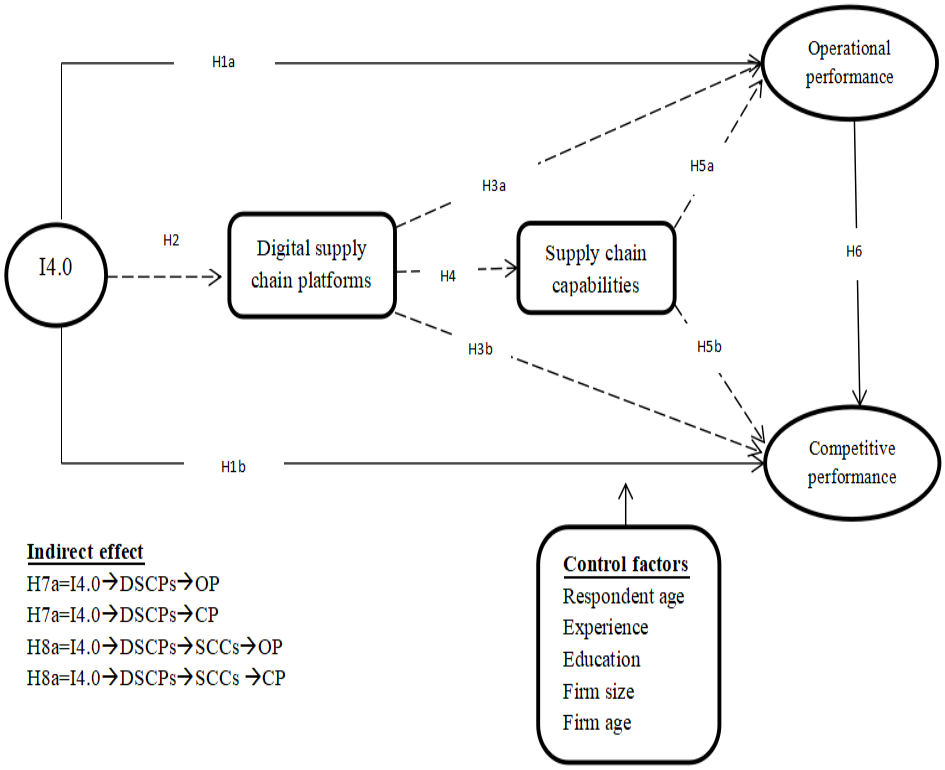


Figure 1: Research Framework

4.2 Research Method: Critical Incident Technique

The critical incident technique was used to survey this study online. Past studies have employed this exploratory method for supply chain surveys. (Dolgui & Ivanov, 2024; Ivanov, Dolgui, & Sokolov, 2022). CIT is used to find empirical human behavior based on a critical or essential event of interest that the researcher wants and the respondent encountered in the past (Janssens, Gelderman, & Petersen, 2023). The incident is defined as issues (related to procurement, operations, distribution, warehousing, and integration practices) that the respondent was involved in during the last five years in managing

personally or through technology, such as Warehouse Management System (WMS) Transportation Management System (TMS) Inventory Management Software Supply Chain Analytics Platform (Janssens et al., 2023). We applied CIT by beginning the survey with open-ended questions that allowed respondents a frame of reference for elaborating on the supply chain innovation policy to issues before answering the survey (i.e., Likert-type scales). Once the problems and managing techniques have been answered as "YES," we request that the participant proceed with the study's primary survey.

4.3 Operationalization of Survey Instrument's Constructs

The study's targeted sample population was the logistics and supply chain managers who had exposure during the last five years to manage logistics and supply chain practices within their current or previous organization through technology, such as Warehouse Management System (WMS), Transportation Management System (TMS) Inventory Management Software Supply Chain Analytics Platform. While designing/moderating the questionnaire, researchers followed the principles (Shaikh & Ahmed, 2022) identified, such as question-wording, construct focus, question sequence, and content length. We kept the focus on the research project objectives and operational definitions of each construct that promote the confidence and interest of respondents. They sought to be as convenient as possible to obtain a suitable and accurate response from the respondents.

I4.0 includes seven constructs to measure the level of adoption. Digital supply chain platform performance was measured using the 4-item scales developed by (Ivanov et al., 2022). SCCs were operationalized as three reflective first-order constructs: Information sharing ($\alpha = 0.90$), Supply chain responsiveness ($\alpha = 0.81$), and Supply chain coordination ($\alpha = 0.80$), following the recommendation that "reflective measurement models are often the most suitable for evaluating SCCs." (Balodi, 2020). The amount to which a business's operational performance (OP) has improved was measured using an 8-item scale derived from the works of (Fosso Wamba & Akter, 2019). Initially, the executives/managers were requested to assess the degree of significance for each item on a 5-point Likert scale, ranging from 1 (indicating minimal importance) to 5 (indicating utmost importance). Subsequently, participants were instructed to evaluate their degree of contentment on the items using a 5-point Likert (1 = not at all satisfied to 5 highly satisfied). Each performance component was assigned a weighted score by multiplying the score for "importance" with the score for "satisfaction." The approach resulted in a high level of reliability, with $\alpha = 0.92$ for OP and $\alpha = 0.91$ for CP. Performance measurement methods have been changed in recent years. Instead of relying on financial or accounting indicators, economic value, or market valuation, perception-based or subjective measures are now being used to assess the extent to which financial indicators are met (Ribeiro et al., 2021). The questionnaire included specific demographic inquiries to characterize the respondents more accurately.

A list of manufacturing firms in the GCC countries is obtained for the survey to examine the empirical results. An online survey was conducted by e-mail (the online Google form questionnaire link) to 858 likely respondents from registered companies of various sizes

from the manufacturing sector in the GCC region. Data were collected from 1st November 1, 2022 to 30th July 2023. After being reminded several times, 390 questionnaires were received. Due to missing data, 41 questionnaires were rejected, leaving 348 valid replies for data processing, a 40.56% evaluation rate.

4.4 Sample Characteristics

Table 1 presents a comprehensive overview of the socio-demographic attributes of the entrepreneurs, as well as the pertinent aspects of their respective businesses. As shown in Figure 1, the study used data from 348 GCC manufacturing supply chain managers and executives to evaluate this study model. Of the participants, 94 (27.01%) were from Saudi Arabia, and 86 (24.82%) were from the UAE. The participants consisted primarily of middle-aged managers and executives, with the majority ranging from 40-49 years old, 114 (32.85%), and above 50 years old, 102 (29.20%). Approximately 29.34% of the participants have engaged in their firms for over 20 years. Notably, 133 (39.07%) participants graduate or have a degree above graduation. Most firms surveyed have between 300 and 400 employees (36.86). In total, 283 (83.25%) are large-size firms (above 300 employees). Likewise, 226 (66.67%) of the firms have an age equal to or greater than 10 years. Collectively, 92 (33.33%) are matured firms.

In conclusion, this study sample attributes show that respondents are mature, highly qualified, and experienced. In addition, most firms are large and mature in age. This may add to this research in terms of responses and empirical findings.

Table 1: Descriptive Summary of the Sample

	Number	Percentage
Countries (n= 348)		
Bahrain	37	10.58
Kuwait	41	11.68
Qatar	46	13.14
Saudi Arabia	94	27.01
Oman	44	12.77
UAE	86	24.82
Age (n=348)		
18 to 30	56	16.06
31 to 40	76	21.90
41 to 50	114	32.85
Above 50	102	29.20
Education (n=340)		
High School and below	49	14.44
Technical/Vocational education	76	22.22
Undergraduate	82	24.26
Graduate and above	133	39.07
Experience (n=342)		
Less than 6 years	51	14.94
6-10	91	26.75
11-20	100	28.97
Above 20	100	29.34
Firm size (n=348)		
50 and less than 50 employees	34	9.67
100 and less than 100 employees	47	13.50
200 and less than 200 employees	74	21.35
300 and less than 300 employees	128	36.86
Above 300 employees	65	18.61
Firm age (n=339)		
Less than 5 years	38	11.12
5–10 years	75	22.11
11–20 years	82	24.22
21–30 years	52	15.35
Above 30 years old	92	27.20

4.5 The Measurement Model

Confirmatory Factor Analysis (CFA) first assessed component convergent and discriminant validity. This was done before SEM was used to test the hypothesized association. The fit indices indicate that the measuring model fits GCC economy data. The chi-square value is 366.16 with 207 degrees of freedom, providing a 0.000 p-value. TLI is 0.86, CFI is 0.88, RMSEA is 0.039, and SRMR is 0.035. The conformance factor loadings (CFA) range from 0.64 to 0.92 (Table 2). These loadings are significant at 0.001. The Composite Reliability (CR) ranged from 0.72 to 0.90, and the Average Variance Extracted (AVE) was 0.64 to 0.79 (Table 2). These values exceed 0.70 and 0.5 limits (Anderson & Gerbing, 1988), verifying measurement item convergence. In conclusion, the Cronbach Alpha (α) values for all constructs in this study exceed the 0.70 threshold, showing strong reliability in measuring the components (Joshi, Singh, & Sharma, 2023; Vaske, Beaman, & Sponarski, 2017).

Table 2: CFA, Reliability, and Validity Tests

Construct		SFL	t-stats	CR, AVE and α
I4.0 Components				
I4.0-1	Internet of Things (IoT)	0.81	8.121	CR= 0.82
I4.0-2	Cyber-Physical Systems (CPS)	0.79	7.983	AVE = 0.71
I4.0-3	Big Data	0.75	8.827	**α = 0.87**
I4.0-4	Cloud Computing	0.81	7.918	
I4.0-5	Robotic Applications	0.73	9.283	
I4.0-6	3 Dimensional Printer	0.81	5.182	
I4.0-7	Augmented Reality (AR)	0.80	6.384	
Digital Supply Chain Platforms				
DSCPs-1	Digital supply chain platforms	0.79	11.283	CR= 0.89
DSCPs-2	Digital platforms with suppliers	0.79	10.532	AVE = 0.64
DSCPs-3	Digital platforms with customers	0.77	9.115	**α = 0.84**
DSCPs-4	Digital platforms with other company units	0.82	8.700	
Supply Chain Capabilities				
A) Information Sharing				
ISC-1	Firm and supply chain partners frequently communicate.	0.80	8.728	CR= 0.90
ISC-2	Firm and supply chain partners communicate well.	0.84	11.555	AVE = 0.67
ISC-3	Firm and supply chain partners communicate business details.	0.87	10.453	**α = 0.90**
IS-C4	Firm and partners Share info promptly	0.83	9.173	
B) Supply Chain Responsiveness				
SCRC-1	Firm supply chain adapts swiftly to consumer needs	0.83	11.479	CR= 0.72
SCRC-2	Firm supply chain adapts to consumer needs	0.87	10.715	AVE = 0.78
SCRC-3	A firm's supply chain adapts fast to competing strategies.	0.91	9.273	**α = 0.81**
SCRC-4	Firm supply chains create new items quickly.	0.86	8.851	

SCRC-5	Firm supply chain adapts to competitors' strategies.	0.92	11.479	
C) Supply Chain Coordination				
SCC-1	Our supply chain partners work well with us.	0.80	10.369	CR= 0.89
SCC-2	Our supply chain partners work well with us.	0.85	9.679	AVE = 0.67
SCC-3	We coordinated supply chain partners efficiently.	0.88	8.377	**α = 0.80**
Operational Performance				
OP-1	Our firm is effective in meeting requirements	0.80	9.097	CR =0.83
OP-2	Our firm is effective in adapting to market changes.	0.85	8.492	AVE = 0.68
OP-3	Our firm is effective in on-time delivery	0.88	7.349	**α = 0.92**
OP-4	We have reduced lead time in fulfilling customers' orders	0.84	7.015	
OP-5	We have effective and reliable quality products	0.89	8.218	
OP-6	We can reduce costs to reach customers	0.88	7.671	
OP-7	We have reduced overhead costs.	0.89	6.639	
OP-8	We have reduced inventory costs.	0.82	6.337	
Competitive Performance				
CP-1	We have increased than our competitors	0.81	10.821	CR= 0.80
CP-2	Our market share increase outpaces competitors.	0.86	10.101	AVE = 0.72
CP-3	Our customer retention is higher than our competitors.	0.90	8.742	**α = 0.91**
CP-4	Our sales volumes have increased compared to the past.	0.85	8.344	
CP-5	Our market share growth has increased compared to the past.	0.91	9.775	

Notes: - SFL = Standardized Factor Loadings; AVE = Average Variance Extracted;
CR = Composite Reliability, a = reliability factor

Table 3 shows the questionnaire construct mean, standard deviation, and correlation matrix. OP has the greatest mean value, followed by SCCs. According to Fornell and Larcker (1981), all constructs' square root of the average variance extracted (AVE) exceeded the correlations, indicating varied validity. The square root of the average variance extracted (AVE) exceeded construct correlations for all constructs. These findings demonstrate that all the elements in the model exhibited discriminant validity, as proposed by (Vaske et al., 2017).

Table 3: Descriptive Statistics and Correlation Matrix

Constructs	Mean	SD	1	2	3	4	5
1. I4.0	3.073	1.073	**0.852**				
2. Digital supply chain platform	3.973	1.032	0.311**	**0.766**			
3. Supply chain capabilities	3.548	0.891	0.372**	0.415**	**0.822**		
4. Operational performance	4.155	1.022	0.266**	0.501**	0.449**	**0.867**	
5. Competitive Performance	3.356	0.749	0.184**	0.134**	0.480**	0.512**	**0.883**

** Correlation is significant at the 0.01 level (2-tailed).

5. Results of Structural Equation Modeling (SEM)

The study used Structural Equation Modeling (PLS-SEM) as it is dependable for complex variable interactions in exploratory research (Thakkar, 2020). PLS-SEM is warranted in your research for many reasons. First, we study latent elements, including Industry 4.0 technologies, supply chain capabilities, company performance, and their relationships (Eslami et al., 2024). PLS-SEM helps evaluate postulated routes and understand dynamic structural linkages in complex models with many components and indicators (Mohammadi et al., 2023; Thakkar, 2020). Second, since PLS-SEM can handle smaller samples than CB-SEM, which requires samples above 500 (Zeng, Liu, Gong, Hertogh, & König, 2021), it fits our 348 survey sample: this benefits limited-resource or scaling-challenged investigations. Finally, PLS-SEM maximizes the dependent variable explained variance (Manley et al., 2024; Marinagi et al., 2023; Zeng et al., 2021). This would aid our research on how digital supply chain capabilities and Industry 4.0 affect corporate success. The method forecasts, making it appropriate for predicting firm performance relationships.

5.1 Direct Effect

This study examined the structural model after the measurement model had a good fit index and was reliable and valid. Structural model results fit indices show an excellent data match: $\chi 2 = 396.68$, df = 188, $\chi 2$ /df = 2.11, p = 0.000, CFI = 0.90, TLI = 0.91, RMSEA = 0.073, and SRMR = 0.038 Exogenous constructions reveal the hypotheses' standardized route coefficients and deviation percentage (R2 value). As depicted in Figure 2, most direct hypotheses were supported, except for H1b and H3b, which received no support.

According to the results, I4.0 significantly influences OP ($\beta = 0.116$, $p < 0.05$) and Digital supply chain platforms ($\beta = 0199$, $p < 0.01$), providing support to the H1a and H1c. However, the study finds no support for H1b. This implies that I4.0 does not predict CP. DSCPs positively influence firm OP ($\beta = 0.225$, $p < 0.05$) and SCCs ($\beta = 0.225$, $p < 0.01$), providing support to H3a and H4. Conversely, DSCP does not predict CP, lending any support to H3b. Moreover, SCC positively predicted firm OP ($\beta = 0.312$, $p < 0.001$) and CP ($\beta = 0.318$, $p < 0.001$), providing support to H5a and H5b. Lastly, OP ($\beta = 0.511$, $p < 0.001$) strongly predicted CP, providing support to H6 of the study. The study included control factors in each model. The R2 values indicated that the model explained 22% and 18% of OP and CP variations in OP and CP with I4.0, 19% in DSCPs with I4.0, 23% and 18% in SCCs with DSCPs, 23% in SCCs with DSCPs, 38% and 29% in firm performance with SCCs and 41% in CP with OP. This study's results indicate that the suggested framework linking I4.0, Digital supply chain platforms, SCCs, and company performance is theoretically and empirically robust.

Table 4: Direct Effect

Hypothesis	IV	DV	Coefficient	R^2	Result
H1a	I4.0	OP	0.116*	22.34%	Supported
H1b	I4.0	CP	0.071	18.51%	Not-Supported
H2	I4.0	DSCPs	0.199**	19.66%	Supported
H3a	DSCPs	OP	0.225*	23.05%	Supported
H3b	DSCPs	CP	0.018	18.75%	Not-Supported
H4	DSCPs	SCCs	0.140**	23.88%	Supported
H5a	SCCs	OP	0.312***	38.40%	Supported
H5b	SCCs	CP	0.318***	29.51%	Supported
H6	OP	CP	0.511***	41.63%	Supported

Notes: *p < 0.05, **p < 0.01, ***p < 0.001 respectively. IV= independent variable, DV= dependent variable, R2= value of R-squared in each model, I4.0 = industry 4 technologies, DSCPs = digital supply chain platforms, SCCs = supply chain capabilities, OP = operational performance, CP = competitive performance

5.2 Mediation Effect

In this stage, the study used mediation analysis to test the effect of I4.0 on the firm's OP and CP via DSCPs and SCCs. For this purpose, the study employed 10,000 bootstrap resampling following the Hayes (2018) PROCESS macro models 80. The effect is considered statistically significant if there is no straddling of zero in the 95% confidence interval (CI). The results are reported in Table 5.

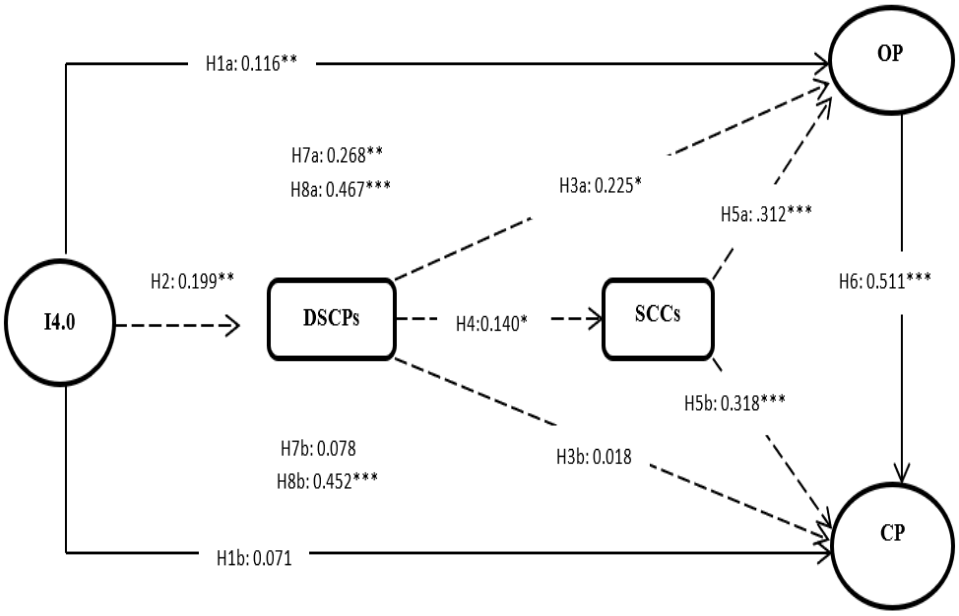
I4.0 significantly and positively impacts firm OP via the DSCPs (β= 0.268**, 95% CI = [0.131, 0.204]), thus accepting H7a. In contrast, I4.0 has no significant indirect impact on

the firm CP via the DSCPs (β= 0.078, 95% CI = 0.031, 0.098]), thus lending no support to H7b. Subsequently, the study examines the empirical validity of the study's proposed sequential indirect effects. The final hypotheses (H8a and H8b) postulate that a sequential mediation process, including DSCPs and SCCs, may explain the impact of I4.0 on firms' OP and CP. The study's findings indicated a positive and significant sequential indirect effect of I4.0 on firm OP, mediated by DSCPs and SCCs (β = 0.467***, 95% CI = [.011, .045]). As the impacts of I4.0 (direct) and (mediation via DSCPs) on OP are statistically significant, the sequential mediation is partial (complementary). Thus, these results partially supported hypothesis H8a. Lastly, results show that I4.0 improves a company's CP sequentially. Specifically, I4.0 influences the DSCPs, affecting SCCs, ultimately influencing firm OP (β = 0.452***, 95% CI = [0.122, 0.259). As the impacts of I4.0 (direct) and (mediation via DSCPs) on CP are statistically insignificant, the sequential impact is full mediation. Thus, these results supported hypothesis H8a. This study's findings demonstrate that the I4.0 in the manufacturing industry positively impacts OP. Additionally, its impact on firm OP is partially mediated by DSCPs and SCCs. However, the insignificant effect of I4.0 on CP is sequentially mediated via DSCPs SCCs. This study's findings indicate that I4.0 in manufacturing positively impacts SCCs via DSCPs, leading to firm performance (OP and CP) through sequential mediation.

Table 5: Bootstrap Indirect Effects of I4.0 on Firm Performance

		β	**S/E**	**95% CI**		
Hypoth	**Direct effect**			**LLCI**	**ULCI**	
H1a	I4.0----> OP	0.116*	0.056	0.082	0.277	
H1b	I4.0----> CP	0.071	0.066	0.030	0.114	
	Indirect effect	**β**	S/E_{Boot}	$LLCI_{Boot}$	$ULCI_{Boot}$	R^2
H7a	I4.0----> DSCPs ----> OP	0.268**	0.112	0.131	0.204	0.347
H7b	I4.0--> DSCPs ----> CP	0.078	0.049	0.031	0.098	0.366
H8a	I4.0---> DSCPs -> SCCs ---> OP	0.467***	0.021	0.141	0.298	0.560
H8b	I4.0---> DSCPs -> SCCs ---> OP	0.452***	0.021	0.122	0.259	0.599

Note: :*p < 0.05; **p < 0.01; ***p < 0.001, OP = operational performance; CP= competitive performance; DSCPs= digital supply chain platforms; SCCs= Supply Chain Capabilities. Control factors are included in each model.



Control factors

Respondent age :-(DSCPs= 0.044; SCCs=0.021; OP=0.008; CP=0.022)
Respondent experience :(DSCPs= 0.050; SCCs=0.023; OP=0.099*; CP=0.136**
Respondent education :(DSCPs= 0.111*; SCCs=0.164**; OP=0.172**; CP=0.188***
Firm age :(DSCPs= 0.098*; SCCs=0.222**; OP=0.159**; CP=0.202***
Firm size :(DSCPs= 0.133**; SCCs=0.181***; OP=0.190***; CP=0.226***

.*p < 0.05; **p < 0.01; ***p < 0.001

Figure 2: SEM Results

6. Discussion on Main Findings

Findings suggest adopting I4.0 technologies influences firms' operational performance (OP). Previous studies partially support these results (Ghobakhloo et al., 2025). The results indicate that a corporation that consistently takes the lead in implementing or synchronizing numerous advanced I4.0 technologies can substantially enhance its operational performance (Ghobakhloo et al., 2025). However, the study finds no significant effect of I4.0 on competitive performance (CP). Adopting I4.0 technologies has been related to improved operational performance (OP) (Rossini et al., 2023). However, the GCC's lack of competitive performance may be due to contextual issues. Previous research implies that I4.0 technologies streamline operations but do not consistently boost competitive advantage (Raj, Kumar, Sharma, & Verma, 2024). Market saturation, cultural

impediments to change, and slow organizational adaptation may hinder I4.0 technology's impact on the competitive performance of GCC enterprises (Almasri, Hewapathirana, Alhashem, Daniel, & Lee, 2023). Competition also depends on market dynamics and strategic positioning, which technology cannot change. These arguments support the insignificant association between I4.0 and OP. Second, I4.0 adoption improves the GCC context's digital supply chain platforms (DSCPs), supporting H2. I4.0 adoption increases GCC Digital Supply Chain Platforms (DSCPs), supporting past research on the role of advanced technology in supply chain capabilities (Salama, Alturjman, Altrjman, & Al-Turjman, 2024). Ivanov (2022) show how IoT, AI, and blockchain offer real-time data exchange, visibility, and seamless coordination, which DSCPs need. In the GCC, where digital transformation and infrastructure investments are rapid, I4.0 adoption helps enterprises optimize logistics, reduce lead times, and improve decision-making, supporting robust digital supply chain ecosystems (Salama, Alturjman, Altrjman, & Al-Turjman, 2024). Further, supply chain capabilities (SCCs) directly affect OP and CP, aligning with the firm's DRBV, which stresses using internal resources to obtain a competitive edge. The DRBV argues that enterprises should constantly adapt and reconfigure their resources and capacities to stay competitive in fast-changing contexts like digital transformation and I4.0 technologies (Salama et al., 2024).

Second, the study used DSCPs to mediate I4.0's effect on firm performance. DSCPs mediate the impact of I4.0 adoption on OP, supporting the dynamic resource-based view (DRBV) (L. Li, Xu, Ning, Liu, & Yang, 2023). The DRBV states that enterprises with advanced technology infrastructures like DSCPs can improve operational efficiency (Kunc, Giorgino, & Barnabè, 2021). I4.0 technologies in supply chain platforms optimize real-time monitoring, inventory management, and predictive analytics, which drive OP (Frederico, Kumar, Garza-Reyes, Kumar, & Agrawal, 2023; Huang et al., 2023). Previous research suggests that digital supply chain solutions improve flexibility, affordability, and reactivity (Choi et al., 2021). I4.0 technology in supply chains can boost OP in the GCC, where digital transformation is emphasized. In addition, DSCPs do not mediate the relationship between I4.0 and CP. Market homogeneity in the GCC may explain competitive parity when enterprises implement identical I4.0 technologies. Frederico et al., 2023; Melnyk, Bititci, Platts, Tobias, & Andersen (2014) found that when enterprises in an industry or region adopt identical technologies, operational efficiency increases may not be enough to provide a durable competitive advantage. Instead, these improvements may bring firms to baseline performance, making it hard for any firm to stand out.

Finally, sequential mediation was employed to determine I4.0 uptake and firm performance links. Following the DRBV framework, the study related resources and capabilities to firms' competitive advantage (de Oliveira-Dias et al., 2023; Helfat, 2009; Helfat et al., 2009). The study used DSCPs and SSCs as sequential mediators that may influence the impact of I4.0 on firm performance. The study finds strong support for H8a and H8b. This study's findings show that I4.0 adoption sequentially affects firm performance (OP and CP) via DSCPs and SCCs. So, adopting I4.0 leads to effective DSCPs (Frederico et al., 2023;

Huang et al., 2023), and the mediation effect of DSCPs on OP is sequentially mediated by SCCs (partial mediation) (Belhadi et al., 2022; Nayal et al., 2022). In the association between I4.0 and CP, sequential mediation is found (full mediation). Hence, SCCs benefit OP and CP and support the DRBV theory.

The study shows that DSCPs and SCCs are crucial intermediary factors that connect I4.0 to the performance of companies in situations when firms require boosting operational efficiency and seek to obtain a CP. According to this study, DSCPs and SCCs help companies improve operational efficiency. Thus, operational efficiency indirectly influences CP. The impact of DSCPs on CP is insignificant for businesses with no SCCs. OP and CP have a positive, statistically significant association. This study's findings confirm the presented hypotheses, which demonstrate that the connection between I4.0 and firm performance (OP and CP) is influenced sequentially by DSCPs and SCCs.

7. Robustness of Main Findings

The study used regression analyses and the Sobel test to determine the robustness of our main findings. For regression, several changes were made to analyze the impact. The study introduced three independent variables: I4.0, DSCPs, and SSCs. The study regressed three separate regressions. Regression 1 and 2 include OP and CP. In regression 3, OP and CP are combined to construct the dependent variable. Further, control factors are also included in the regression analyses. Table 6 presents the findings of regression analyses. The results are similar to those reported in Table 4 above. Thus, our results are also robust to other regression analyses. In addition, the study provides in-depth insight into the firm overall performance by using it as a second-order construct of OP and CP. The results are similar to those reported in Table 4 above.

Table 6: Robust Regression Analysis

	Regression 1		**Regression 2**		**Regression 3**	
	Dependent variable= OP		**Dependent variable= CP**		**Dependent variable= SP**	
Variables	β	**t-stat**	β	**t-stat**	β	**t-stat**
I4.0	0.122*	1.998	0.084	1.155	0.109*	2.081
DSCP	0.211*	2.190	0.016	1.382	0.107*	2.038
SSC	0.371***	4.130	0.335***	4.179	0.304***	4.164
OP			0.522***	5.304		
Control factors						
Respondent age	0.088	1.057	0.112	1.073	0.093	1.071
Respondent experience	0.105*	2.197	0.099*	2.311	0.141*	2.108
Respondent education	0.155**	3.108	0.106***	2.982	0.132**	2.994
Firm age	0.344**	0.148	0.288**	0.208	0.259**	0.049
Firm size	0.512***	3.144	0.484***	2.898	0.455***	3.088
Adjusted R-square	0.689		0.645		0.701	

Note: OP = operational performance; CP= competitive performance; DSCPs= digital supply chain platforms; SCCs= supply chain capabilities, SP= sustainable performance, ***, ** and * represent P<0.001, P<0.01 and P<0.05,

The study employed Sobel tests to explore indirect effects or mediating connections between predictor factors (I4.0) and outcome variables (OP and CP) through mediator variables (DSCPs and SSCs). As indicated in prior studies, the Sobel test in Table 7 determines the mediation effect significance (Christofi, Khan, Zahoor, Hadjielias, & Tarba, 2023; Sobel, 2008). The indirect effect of I4.0 on OP through DSCPs and the sequential mediation effect on OP and CP through DSCPs and SCCs are statistically significant. The indirect effect of I4.0 on CP via DSCPs is not statistically significant, rejecting H7b. Thus, hypothesis 7a for indirect effect and H8a and H8b for sequential mediation are validated.

Table 7: Sobel Test

Hypotheses	**Sobel test**		
Mediation effect	**S/E**	**Z-value**	**Result**
H7a= I4.0→ DSCPs→OP	0.052	5.226***	Mediation
H7b= I4.0→ DSCPs→CP	0.046	1.717	Not supported
Sequential Mediation effect			
H8a= I4.0→ DSCPs→ SSCs→OP	0.071	6.643***	Mediation
H8b= I4.0→ DSCPs→ SSCs→CP	0.158	2.899**	Mediation

***, ** and * represent P<0.001, P<0.01 and P<0.05

8. Research Contribution and Limitations

First, the analysis suggests that I4.0 adoption does not ensure company efficiency. The managers should follow a sequential approach to maximize the economic benefits of I4.0 in emerging economies. I4.0 can help digital supply chain platforms and SCC owners compete. This integrated approach provides them with efficiency in operation and competitiveness. One of the most important outcomes of the current study is the insignificant association between I4.0 and firms' CP. The sequential approach can be used to maximize the advantage of I4.0 adoption. Second, digital supply chain platforms can provide operational efficiency. However, managers can use it as a sequential mediator via SCCs to achieve efficiency (OP and CP). So, the insignificant association between digital supply chain platforms and CP does not imply that this factor is irrelevant. Therefore, managers must establish a framework to maximize the advantage of I4.0 adoption. Third, SCCs are a factor that requires managerial attention. It strongly predicts firm performance and aligns the built-in technological edge with firm efficiency. Hence, this report underlines the need for supply chain and operations managers to evaluate the compatibility of supply chain partner platforms. I4.0 might be a significant seismic shift occurring within the GCC economies. The potential for economic, societal, and environmental transformations is evident with the emergence of I4.0 technologies, including the Internet of Things (IoT), big data analytics, cloud computing, and artificial intelligence. The GCC region has had significant business challenges, substantially hindering its economic progress. Similar to developed economies, GGC nations have the potential to leverage the opportunities presented by the Fourth Industrial Revolution (I4.0) to address their developmental obstacles. The authorities have set a strategic objective to effectively leverage advanced information and communication technologies (ICTs) by 2030 to foster economic development and expansion. Technology is transforming GCC manufacturing. Using "I4.0" technology like AI and robots, the sector is becoming more connected, automated, and data-driven. Supply chain success in I4.0 technical progress has policy consequences. There is a need to shift modernized supply chain platforms that may help organizations maximize their advantage. In addition, the authorities should assist manufacturing sectors in acquiring SCCs so that I4.0 may be a competitive edge for these organizations. This shift enhances efficiency and productivity and can stimulate the region's endeavors towards economic diversification and enhance its competitiveness in supply chain management, thereby generating novel employment prospects and restructuring its financial framework.

8.1 Theoretical Contributions

This paper contributes to the Digital Resource-Based View (DRBV) by demonstrating Industry 4.0 (I4.0)'s impacts on firm operational and competitive performance in a developing market setting, precisely the GCC context. Our findings contradict the prevailing thinking by indicating that i4.0 improves competitive performance but not

operational performance. With further investments in supporting skills, GCC enterprises may be able to capitalize entirely on operational benefits through i4.0.

Additionally, our research emphasizes the importance of digital supply chain platforms and capacities as mediating factors. The high mediation effect between I4.0 and company performance suggest how digital technologies boost competitiveness and operational efficiency in an integrated supply chain. This study adds to the DRBV the dynamic role of digital infrastructure in emerging market business performance.

8.2 Limitations and Future Research

The present work exhibits several limitations that warrant further investigation in future research endeavors. The research utilized cross-sectional data, whereas a longitudinal research study has the potential to examine the potential impacts of compatibility dimensions before, during, and after the adoption of I4.0. The research utilized survey data collected from logistics and supply chain managers; it would be more beneficial if studies considered the viewpoints of other supply chain participants at various levels. Furthermore, due to the intricate and context-dependent characteristics of the diverse aspects of I4.0 and SCC factors previously identified in scholarly investigations; it was unfeasible to encompass the entirety of these constructs within a single study. Thus, future studies should examine how supply chain integration affects other SCCs and external moderating factors that may affect the relationship between I4.0 technologies and business performance. Operational, technological, and cultural compatibility of I4.0 may also affect this integration in different ways. In conclusion, considering digital transformation and I4.0, the importance of the intricate process of supply chain management theory, and the participation of big manufacturing businesses within the supply chain, doing additional empirical research in other industry contexts has the potential to enhance the applicability of the model and the conclusions put forth by this study.

Given the growing importance of supply chain resilience, future research should examine how Industry 4.0 affects a firm's long-term resilience. Research might examine how IoT and AI in supply chains improve competitive performance and firm resilience and agility in the face of global catastrophes like pandemics and geopolitical conflicts.

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Appendix A. Operational Definitions of Constructs

Construct	Operational definition
Dynamic resource-	DRBV combines RBV and DCV to enhance RBV's effectiveness in achieving long-term competitive advantage. It emphasizes the ability to reconfigure resources and capabilities over time adaptively (van den

based view (DRBV)	Hende, Riezebos, & Coelen, 2023). DRBV illustrates how resources and capabilities can result in long-term competitive advantages (Chen, Michel, & Lin, 2021)
Industry 4.0 technologies (I4.0)	I4.0 revolves around integrating information and communication technologies to effectively combine the physical and virtual domains, creating a cohesive network of resources, information, and people. Industry 4.0 tools facilitate the integration of critical functions to seamlessly interchange shared data and information across multiple supply chains (Frank, Dalenogare, & Ayala, 2019; Zheng, Ardolino, Bacchetti, & Perona, 2021).
Digital supply chain Platforms (DSCPs)	DSCPs emerge directly from information and communication technology developments. These platforms are defined as the technologically advanced systems a firm has implemented to enable the efficient and smooth flow of supply chain-related information within the organization and with external partners. DSCPs are a fusion of technology components (software and hardware) with associated organizational processes and standards (Yevu, Ann, & Darko, 2021). This DSCP network facilitates internal and external communication beyond organizational boundaries (Govindan, Rajeev, Padhi, & Pati, 2020).
Firm competitive performance	(Garcia-Buendia, Moyano-Fuentes, Maqueira-Marín, Romano, & Molinaro, 2023) have highlighted the firm performance by gaining a competitive advantage in the market.
Firm operational performance	Operational performance measures the best use of resource allocation to gain above-average profit, including efficiency in resource allocation, optimal asset utilization, and faster operations (Buhulaiga & Telukdarie, 2024).