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ADOPTION OF ARTIFICIAL INTELLIGENCE AND DIGITAL SUPPLY CHAIN FOR ENHANCING SUPPLY CHAIN PERFORMANCE: MEDIATING ROLE OF GREEN SUPPLY CHAIN PROCESS

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Research Paper

Abstract: *Research empirically tested the impact of artificial intelligence adoption and digital supply chains on supply chain performance with the mediating effect of green supply chain process of manufacturing companies in Saudi Arabia. For this purpose, cross-sectional data collected from 330 employees working in manufacturing firms' by using self-administered questionnaires and employing a convenient sampling technique. Partial Least Square (PLS)-Structural Equation Modeling (SEM) technique employed in two measurement and structural models. The results show that AI-based business and marketing, AI-based risk management, AI-based power workforce, and AI-based big data analytics have a positive and significant impact on supply chain performance. Digital supply chain and green supply chain process also positive and significant impact on supply chain performance. Further indirect effect results show that the green supply chain process is also partially mediated among AI-based factors, digital supply chain, and supply chain performance of manufacturing companies in Saudi Arabia. The study with these findings suggested that manufacturing companies in Saudi Arabia should prioritize the integration of AI technologies and digital supply chain processes to enhance supply chain performance. Additionally, focusing on green supply chain practices can further amplify the benefits of AI and digital transformation that could increase the supply chain performance and competitive advantage of the organizations.*

Keywords: *Artificial intelligence, Digital supply chain, Supply chain performance, Big Data.*

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1. Introduction

Supply chain performance (SCP) efficiency is a key to any business's success, especially in manufacturing, where operational efficiency and cost reduction are major concerns (Yousefi & Tosarkani, 2023). In the supply chain, companies should monitor products, information, and service efficiency (Rashid, Rasheed, Tanveer, et al., 2024). Efficient Supply Chain Performance (SCP) also helps reduce operating costs, increase productivity, improve delivery times, and meet the demands of rapid change in changing markets (Emon et al., 2024). As companies face global competition, it is clear that improving SCP is not just an option but a necessity for growth and profitability which also improves efficiency and effectiveness (Karmaker et al., 2023). These previous studies emphasized that SCP is an important factor for the organization which improves the company's competitive advantage. This is the reasons, in extant literature it becomes the area of research for the researchers.

The SCP can be improved through a variety of methods, the most important of which focuses on coordinating and managing the green supply chain process (Rad et al., 2022). The integration of advanced technologies could greatly improve the speed, accuracy, and flexibility of operations. Through the development of adopting technologies, companies can ensure that customer requirements are met promptly while maintaining cost efficiency (Belhadi et al., 2024). Additionally, the importance of the green supply chain process (GSC) to enhance overall supply chain efficiency, reduce corporate waste, reduce carbon footprint, and enforce negative practices of environmental concerns in line with consumer preferences have gained importance in this development (Toorajipour et al., 2021). The business performance and reputation of these firms enable them to grow, thus contributing to long-term prosperity. These studies emphasized that GSC is a major area of research that could help to improve the SCP. Therefore, this study focused on the impact of the GSC on SCP.

In the extant literature, artificial intelligence (AI) has become an emerging technology that enhances the culture of GSC of organizations (Toorajipour et al., 2021). AI applications have proven to be powerful tools for optimizing various components of the supply chain (Pournader et al., 2021). AI can increase the accuracy of predictions, improve demand processing, streamline inventory management, and enable real-time decision-making which helps to improve supply chain operations (Belhadi et al., 2024). The AI-powered system helps organizations analyze the data to identify the patterns that could help to make data-driven decisions that mitigate risk and optimize (Rashid, Baloch, et al., 2024). For example, AI-based risk management systems help identify problems with the possibility of occurrence in the supply chain as well as this risk (Wong et al., 2024). In addition, AI-powered automation tools increase employee productivity by automating routine tasks, reducing human error, and enabling faster responses to market changes (Rane et al., 2024). The integration of AI into supply chain management has shown significant developments in profitability (Queiroz et al., 2021). It is a priority for companies looking to stay ahead in a competitive global marketplace (Wong et al., 2024). Along with AI technologies, the digital supply chain also becomes an important factor for organizations which improves the supply chain process of the organization. These studies focused on the impact of AI technologies and digital supply chains on SCP through the GSC.

Through the significance of AI technologies, digital supply chains, and GSC for SCP, extant literature still has various gaps. For instance, earlier researchers have mainly

focused on the direct effect of AI technologies, and digital supply chains on SCP ((Ajiga et al., 2024;Al Bashar et al., 2024;Lee et al., 2022 ; Queiroz et al., 2021). In other contexts, most studies focused on the application of AI in individual areas such as materials conservation management or predictive analyses are emphasized but do not examine its overall impact on the entire SCP (Ajiga et al., 2024; Lee & Zhang, 2023). Furthermore, extant studies also focused on the individual impact of the digital supply chain on performance (Le et al., 2024; Lee et al., 2022; Queiroz et al., 2021) with limited attention on SCP. Also, the digital supply chain has limited attention to SCP impact along with AI technologies as independent variables. Therefore, this study focused on the combined effect of both digital supply chain and AI technologies on SCP.

In addition, most existing research has focused on AI's direct effects in other economies with limited empirical evidence from the Middle East, especially within the context of Saudi Arabia's manufacturing sector (Belhadi et al., 2024; Helo & Hao, 2022; Le et al., 2024; Lee & Zhang, 2023; Toorajipour et al., 2021). While there is considerable research on AI's impact in other regions, the unique economic and regulatory environment in Saudi Arabia has not been sufficiently explored in the context of AI technologies, and digital technologies to impact supply chain performance. Moreover, most of the studies have largely ignored the role of mediating factors like the green supply chain process which could enhance the impact of AI technologies and digital supply chain on SCP. The need for more research focusing on Saudi Arabia's manufacturing sector is critical which aims to diversify country economy. Thus, based on previous studies' gaps, the study aimed to test the impact of AI technologies and digital supply chains on SCP with the mediating role of GSC of Saudi Arabia manufacturing companies.

The study has significance from both theoretical and managerial perspectives. This study has contributed AI technologies and digital supply chain in one model to increase the SCP through improving the green SCP because this has been underexplored in the existing literature. From a theoretical perspective, this research expanded the body of knowledge by addressing the gap related to AI's direct and mediated impact on SCP. It also contributes to the understanding of how AI can be utilized as a strategic tool to enhance overall supply chain efficiency, a factor that is under-researched in the context of the Middle East. On the other hand, managerial perspective, study has the significance because this study offers a valuable understanding for practitioners and policymakers particularly within Saudi Arabia's manufacturing sector by demonstrating how AI integration can optimize GSC which improve decision-making, mitigate risks, and drive sustainability. The findings could also inform managers and policymakers on how to leverage AI to achieve enhanced SCP, aligning with the country's Vision of industrial modernization and achieving competitive advantage. The study was further divided into four chapters, literature review, research methodology, data analysis, and results, discussion, and implications.

2. Literature Review

2.1 Theoretical Review

Presented model in Figure 1 shown the relationship between advanced technologies such as AI, Digital Supply Chain (DSC) and Supply Chain Performance with the mediating effect of Green Supply Chain (GSC) which comes under resource-

based view (RBV) theory (Chen et al., 2022). This shows that leveraging unique technologies can provide firms have gained competitive advantages, in particular achieving efficiency and sustainability in supply chain practices (Ferreira et al., 2016). By creating intention on GSC organizations could not only reduce costs and increase operational efficiency but also meet environmental objectives, contributing to a system broadly related to supply chain performance (Barney et al., 2001). In another context, the incorporation of AI technologies and DSC is also consistent with the dynamic theory of power, focusing on how organizations can adapt to rapidly changing environments enabling them to recognize opportunities, seize them, and restructure to respond to market fluctuations (Dwivedi et al., 2021) which meets to improve the supply chain of the organization. For supply chains, this dynamic capability is critical to improving SCP because it facilitates greater responsiveness, flexibility, and also real-time decision-making in the organization (Ahmed et al., 2023). Furthermore, relationships between GSC and SCP highlighted the critical importance of environmental sustainability practices in supply chain management. This is in line with the triple bottom line (TBL) principle, which emphasizes the need for corporate competitive advantage. Theoretically, it has been found that AI technologies and digital supply chains are important indicator in improving the GSC which helps to improve the SCP which is predicted in Figure 1 below,

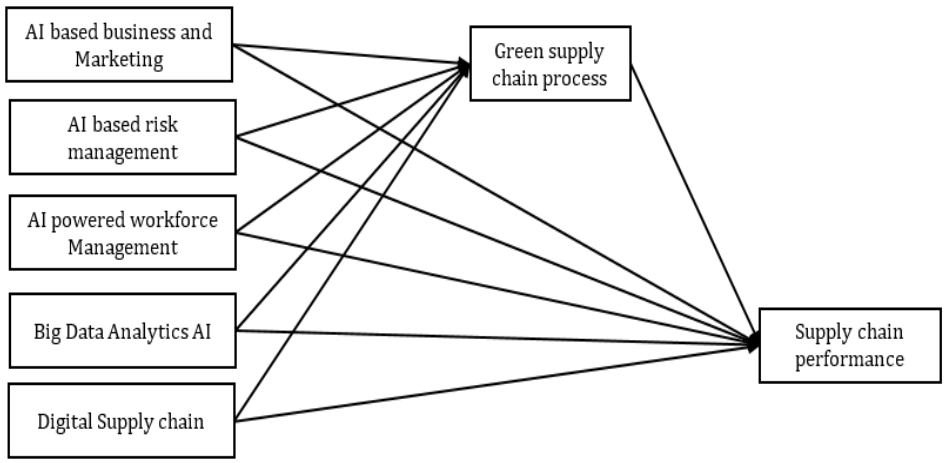

Figure 1: Theoretical Framework

2.2 Hypothesis Development

AI-based business and marketing use AI technologies to improve decision-making processes in terms of demand forecasting, and customer targeting. These tools help to define the market which aligns with the supply chain operations with customer preferences (Queiroz et al., 2021) . AI-based marketing strategies improve demand planning and enable better alignment of supply chain operations with market needs (Helo & Hao, 2022). This reduces inventory costs and improves customer satisfaction (Helo & Hao, 2022). AI-driven business marketing strategies, including demand forecasting, dynamic pricing, and customer behavior analysis, have a significant impact on supply chain performance(Dash et al., 2019). These strategies for supply chain improve burial management, optimize manufacturing processes, and align supply chain operations with customer needs. For example, (Queiroz et al., 2021)

showed that AI in marketing dramatically increased SCP by reducing stockouts and excess inventory through better demand forecasting and customer insights. (Belhadi et al., 2024) also showed that AI-driven marketing analytics strengthened collaboration between supply chain partners, resulting in improved supply chain performance. (Mahi, 2024) found that AI-powered marketing analytics helped businesses make more accurate forecasts which leads to reduced operational costs and increased timeliness (Dubey, Bryde, Blome, et al., 2021) also confirmed that AI-based marketing strategies enabled firms to better plan production and distribution to improve the supply chain performance. Shobhana (2024) further also emphasized that AI-based marketing insights help companies transform their supply chain operations which could improve the firm's SCP. Based on previous studies, a study has formulated the following research hypothesis below,

H1: *AI-based business and marketing significantly effect on SCP.*

Furthermore, AI-based risk management uses AI technology to identify, anticipate, and mitigate risks in the process of manufacturing (Dubey, Bryde, Foropon, et al., 2021). In other words, AI-based risk management increases better decision making which is proactive to increase SCP. This leads to efficiencies, reduced costs, and improved reliability throughout the supply chain. AI risk management helps to transform risk management in the operations, especially in their supply chain. Groenewald et al. (2024) further showed that AI-driven systems provide real-time insights into potential risks, and enable firms to change operations quickly which is improving supply chain reliability. Olutimehin et al. (2024) also further found that predictive analytics tools of supply chain bottlenecks and other risks aid in discovery enabling companies to minimize disruption and improve operational results which improve the SCP. Ahmed further supported these findings, that AI-driven risk management systems reduced operational delays and increased decision-making, which improved supply chain performance. They also emphasized that AI-driven risk management reduced risk and increased responsiveness allowing for monitoring related to performance. After keeping previous literature, the study has formulated the following research hypothesis below,

H2: *AI-based risk management has a significant impact on SCP.*

AI-powered workforce integrates intelligent tools to enhance human capabilities in supply chain tasks such as scheduling, logistics, and inventory control (Fountaine et al., 2019; Olawale et al., 2024). AI-powered tools increase employee productivity, accuracy, and decision-making in supply chain operations (Fountaine et al., 2019). AI-powered optimization tools, which help to transform supply chain operations through improving employee productivity. AI-driven scheduling systems enable companies to better align employee resources with production schedules, improving efficiency and reducing costs. Kumar et al. (2024) found that AI tools for inventory management have improved employee productivity, resulting in better analysis and control over supply chain management which improves the supply chain performance. Rane et al. (2024) also highlighted that AI-enabled labor management systems have helped to streamline labor scheduling and improve overall operational efficiency increasing the supply chain performance. Based on the previous discussion, a study has formulated the following research hypothesis below,

H3: *AI-powered workforce has a significant impact on SCP.*

AI-based data Analytics uses AI algorithms to analyze and interpret vast amounts

of supply chain data which helps to provide accurate and predictive decision-making. AI-powered data analytics make supply chains more informed, and more efficient. They enable companies to identify inefficiencies, improve efficiency, and increase customer satisfaction through data-based insights (Belhadi et al., 2024). AI-powered data analytics has become important for improving SCP through improving more accurate demand forecast decision-making. Further study also identified that AI-based data analytics platforms deliver real-time visibility which helps companies to quickly identify bottlenecks which increases the SCP (Belhadi et al., 2024) and also found that AI analytics tools helped companies to identify inefficiencies, enable efficiencies and improve SCP. Riahi et al. (2021) showed that AI-driven data insights improved production scheduling and reduced lead times which increases the supply chain performance. Yanamala (2023)supported these findings, arguing that AI-based data analysis systems improved logistics and reduced operating costs which could contribute to improving supply chain performance. The hypothesis is formulated based on previous literature.

H4: *AI-based data analytics has a significant impact on SCP.*

DSC where uses technologies to digitize and optimize supply chain processes which ensures seamless integration and transparency (Belhadi et al., 2024). DSC increase operational efficiency, reduce costs, and improve how customers' needs are improved (Rane et al., 2024). They also promote better collaboration between stakeholders and provide real-time visibility into SCP. Digitizing supply chains through incorporating technologies also played a key role in increasing supply chains (Lee et al., 2022). They also further argued that the digital supply chain increases the culture of technology which increases the SCP of the organization. (Rashid, Rasheed, Ngah, et al., 2024) also found that DSC enables improved communication and responsiveness among supply chain partners, reduces delays, and improves logistics quality, resulting in better efficiencies. Ngo et al. (2023) further argued that DSC integration allows real-time management which helps to improve stockout and delivery of goods on time. Rahamneh et al. (2023) also highlighted that DSC improved logistics operations by providing more accurate tracking and minimizing cost which is relevant to operations which in turn improved SCP. Based on previous discussion, it is hypothesized that,

H5: *Digital Supply Chain has a significant on Supply Chain Performance.*

Furthermore, GSC is also an important indicator of improving the supply chain performance. The GSC helps to reduce carbon footprints and waste by integrating environmentally sustainable practices to increase SCP. GSC increases operational efficiency, conforms with environmental regulations, and builds brand reputation (Lai et al., 2023). They also further argued that it contributed to long-term cost savings and aligned supply chain objectives with sustainability objectives. Integrating green supply chains not necessarily helps the environment but it also improves SCP by improving the efficiency of the organizations. Karmaker et al. (2023) also found that the adoption of green supply chains like as sustainable transportation and energy efficiency, reduced costs, and improved resource efficiency, which improved supply chain performance. Green practices may help firms reduce environmental impact and improve profitability and productivity. Hashmi (2023) indicated that GSC also improves customer satisfaction by enhancing demand for environment-friendly products that increase the SCP. Rashid, Baloch, et al. (2024) further found that incorporating sustainability practices in supply chain management reduces operating

costs and becomes a supply chain strategy effective and efficient which increases the supply chain performance. Based on the previous discussion, a study has formulated the following research hypothesis below,

H6: *Green Supply Chain has a significant impact on Supply Chain Performance.*

2.3 Mediating Role of Green Supply Chain (GSC)

Extant literature has found that AI technologies become an important transformative tool that directly helps to improve the SCP by enhancing efficiency, accuracy, and agility (Belhadi et al., 2024). AI technologies allow firms to optimize inventory management, and enhance transportation efficiency which leads to cost savings and improved customer satisfaction (El Jaouhari & Hamidi, 2024). For example, AI-based demand forecasting helps to control the stocks through accurately predicting the needs of the market which helps companies to maintain a proper inventory level of their products (Ma et al., 2024) which increases the supply chain performance. On a parallel side, the GSC also improves the SCP through the development of environmentally friendly products (Ghaderi et al., 2024). Practices like sustainable sourcing, waste minimization, and eco-friendly packaging not only help to minimize the carbon footprints but it is also help to align with consumer preferences for ethical products (Srivastava, 2007). Dahinine et al. (2024) further highlighted the importance of GSC to increase the SCP through strengthening resilience on an organizational level which enhances corporate reputation, and leads to long-term cost reductions which improve the supply chain. In light of previous literature, GSC is an important indicator of improving SCP. These studies have majorly focused on direct effects but have limited attention to indirect effects

Extant literature has emphasized that AI-based technologies play an integral role in increasing the green supply chain by enabling more sophisticated and efficient sustainability measures (Rashid, Baloch, et al., 2024). AI-based technologies that provide real-time insights into energy consumption, emissions, and waste levels are allowing firms to identify inefficiencies and implement corrective actions (Rashid, Baloch, et al., 2024) that could increase supply chain performance. In other words, AI-based demand optimization could also determine the more effective delivery system which increases the SCP(Srivastava, 2007). In the same vein, AI technologies also helped to increase green procurement by fulfilling the complaints of their customers with environmental standards and facilitating the selection of sustainable sourcing partners (Hong & Xiao, 2024). AI I an important factor in product lifecycle management by forecasting the environmental impact of products at various stages, enabling companies to design more eco-friendly products and packaging (Rathor, 2023). Furthermore, through the automated green auditing process, organizations can improve the cost efficiency which is making GSC more accessible and impactful for each business (Rane et al., 2024).

These previous studies emphasized that AI integration with GSC has a greater influence on SCP. Equally, the DSC is also an important factor in increasing the supply chain performance. Improves the process and analyzes vast amounts of data enabling companies to implement dynamic green strategies that adapt to changing environmental conditions and regulatory requirements (Belhadi et al., 2024). Improves the usage of energy usage which increases the SCP (Benzidia et al., 2021). A DSC not only strengthens green supply chain initiatives but also improves overall SCP by reducing operational costs, enhancing resource utilization, and meeting

stakeholder expectations for environmental responsibility (Nwagwu et al., 2023). Along with AI technologies, the DSC also becomes an important factor for organizations that improves the GSC of the organization. Based on previous, studies focused on the impact of AI technologies and digital supply chains on SCP through the supply chain process.

H7: *AI-driven business and marketing significantly influence to SCP with GSC acting as a mediator.*
H8: *AI-enabled risk management has a significant influence on SCP with GSC acting as a mediator.*
H9: *AI-powered workforce capabilities significantly influence on SCP with GSC acting as a mediator.*
H10: *AI-driven data analytics significantly influence on SCP with GSC acting as a mediator.*
H11: *DSC capabilities have a significant influence on SCP with GSC acting as a mediator.*

3. Research Design

Research empirically tested influence of artificial intelligence and digital supply chains on supply chain performance by the mediating effect of the green supply chain process of non-financial companies in Saudi Arabia. Quantitative data collection employed through cross-sectional design because the survey instrument was a self-administered questionnaire (Cheung, 2021). This research design helps in data collection at a single point in time, which making it a cost-effective and convenient approach for examining population characteristics and exploring relationships between variables. This is also useful for the various patterns identifications, trends, and associations in large samples (Olson et al., 2021). Therefore, a study has used the cross-sectional research design.

3.1 Questionnaires and Sampling Technique

The research instrument was adopted from extant literature where it was already tested. Digital supply chain is measured by five items (Lee et al., 2022), and SCP is also measured by five items (Lee et al., 2022). AI-based workforce management measurement by five items five items(Kumar et al., 2024). AI business and marketing are measured by four items (Kumar et al., 2024). Big data AI is measured by four items(Benzidia et al., 2021). AI risk management is comprised of three items of (Dubey, Bryde, Foropon, et al., 2021). Lastly, the GSC which was measured through green supply chain collaboration measured by four items (Benzidia et al., 2021). Variables were measured on a point Likert Scale. Study population was employees of Saudi Arabia employee's manufacturing sector employees. From the population, data was collected using a convenient sampling technique from non-financial sector employees. The convenient sampling technique was chosen because it is more practical and easy to access for the participants, especially in a setting where time and resource constraints are a factor. Furthermore, the nonprobability sampling technique also helps to collect data quickly and effectively from the respondents (Etikan et al., 2016). Questionnaires were distributed among 450 employees which provided a strong basis for statistical analysis and increased the likelihood of diverse responses. Among these, 330 questionnaires were returned which yields a high

response rate. Large size of sample increases the study findings strength through enhancing the representativeness and reliability of the data, as it reduces sampling error and increases the statistical power of the analysis (Kotrlik & Higgins, 2001). Collected data was analyzed in two software's, SPSS and Smart PLS 4.

3.2 Common Method Biased

To address the biases of the responses, early and late respondents resposnes were compared following the method (Armstrong & Overton, 1977). To prevent common method bias (CMB), several statistical remedies were applied, including Harman's single-factor test, collinearity test, and marker-variable technique. The Harman test showed the variance of the first factor which is only 41% of the variance which is less than 50% which shown no issue of CMB (Aguirre-Urreta & Hu, 2019). The marker-variable technique revealed minimal differences between manifest variables, indicating low CMB. Additionally, the values of the mulicollinearity which was measured by VIF (variance inflation factors) also less than 3.33 which confirmed that no issue of VIF. These results indicated that there is no issue of CMB.

3.3 Demographic Table

Table 1 results show the demographic results of the study which is of 330 respondents of Arabia manufacturing companies. These results show that the majority of in the range of age 35-44 (27.3%), indicating a relatively young workforce. Gender distribution reveals a higher proportion of male respondents in manufacturing companies (57.1%) compared to non-manufacturing companies, where females make up 50% of the sample. Education-wise, the majority hold a Bachelor's degree (51.5%), with manufacturing companies having a slightly higher representation of individuals holding a Doctorate degree (14.3%). In terms of salary, most respondents earn between 5,000 and 10,000 SAR (36.4%), with a notable proportion of those in manufacturing companies earning more than 20,000 SAR (14.3%), suggesting that manufacturing companies may offer slightly higher salaries. The above results are predicted in Table 1.

Table 1: Demographic Characteristics

Demographic Category	Subcategory	Frequency (N)	Percentage (%)
Age	18-24	40	12.10%
	25-34	120	36.40%
	35-44	90	27.30%
	45-54	60	18.20%
	55+	20	6.10%
Gender	Male	180	54.50%
	Female	150	45.50%
Education	High School	50	15.20%
	Bachelor's Degree	170	51.50%
	Master's Degree	80	24.20%
	'Doctorate	30	9.10%
Salary (SAR)	Less than 5,000 SAR	60	18.20%
	5,000 to 10,000	120	36.40%
	10,001 to 15,000	80	24.20%
	15,001 to 20,000	40	12.10%
	Above 20,000	30	9.10%

3.4 Measurement Model

The research hypothesis was tested using the Partial Least Squares (PLS) Structural Equation Modeling (SEM) through Smart PLS-4. The next section shown the results of results of measurement model

3.5 Convergent Validity

The convergent validity asses the degree to which shows that the two same constructs are correlated which is showing that they are efficiently capturing (Hair Jr et al., 2017). It is demonstrated when different methods or items measuring the same construct show strong agreement. Convergent validity ensures that multiple indicators effectively measure the same underlying construct, and it is assessed using key metrics such as "factor loadings, composite reliability, Cronbach's alpha, and Average Variance Extracted (AVE)" (Cheung & Wang, 2017). Factor loadings showed the corrections among the items with a threshold value of greater than 0.7 (Cheung & Wang, 2017). Alpha represents constructs internal consistency along with a threshold of 0.7 where 0.8 shows good reliability and above 0.90 shows excellent consistency (Vaske et al., 2017). AVE measures the variance captured by the construct relative to measurement error, requiring a value of ≥ 0.50 showing construct has the convergent validity (Hair Jr et al., 2017). The above results are predicted in Table 2 below.

Table 2: Convergent Validity

Construct	Cronbach's Alpha	Composite Reliability (CR)	AVE
AIB&M	0.915	0.94	0.796
AIBRM	0.869	0.906	0.708
AIPW	0.923	0.94	0.761
DAAI	0.884	0.92	0.742
DSC	0.975	0.98	0.908
GSC	0.894	0.927	0.762
SCP	0.858	0.897	0.637

Source: Author's Estimation

Note: AIB&M-artificial intelligence-based business and marketing, AIBRM-artificial intelligence-based risk management, AIPW-artificial intelligence-based powered workforce, DAAI-data analytics artificial intelligence, DSC-digital supply chain, GSC-green supply chain process, SCP-supply chain performance,

3.6 Discriminant Validity

Discriminant validity ensures that the construct is different from each construct in the study model which demonstrates that indicators are uniquely measured from another construct. The discriminant validity could be measured three criteria's (Henseler et al., 2015). Firstly, Fornell-Larcker showed that each construct square root of AVE in diagonal values should be greater than the below values of the construct (Siyal et al., 2022). Cross-loadings confirm discriminant validity when an indicator's loading on its construct. HTMT assesses the similarity between constructs, with a threshold value of < 0.90 (or < 0.85 for stricter models) showing discriminant construct validity (Henseler et al., 2015). Among the discriminant validity criteria in Table.3 predicted values show that all diagonal values are greater than the below values which fulfills the criteria of discriminant validity.

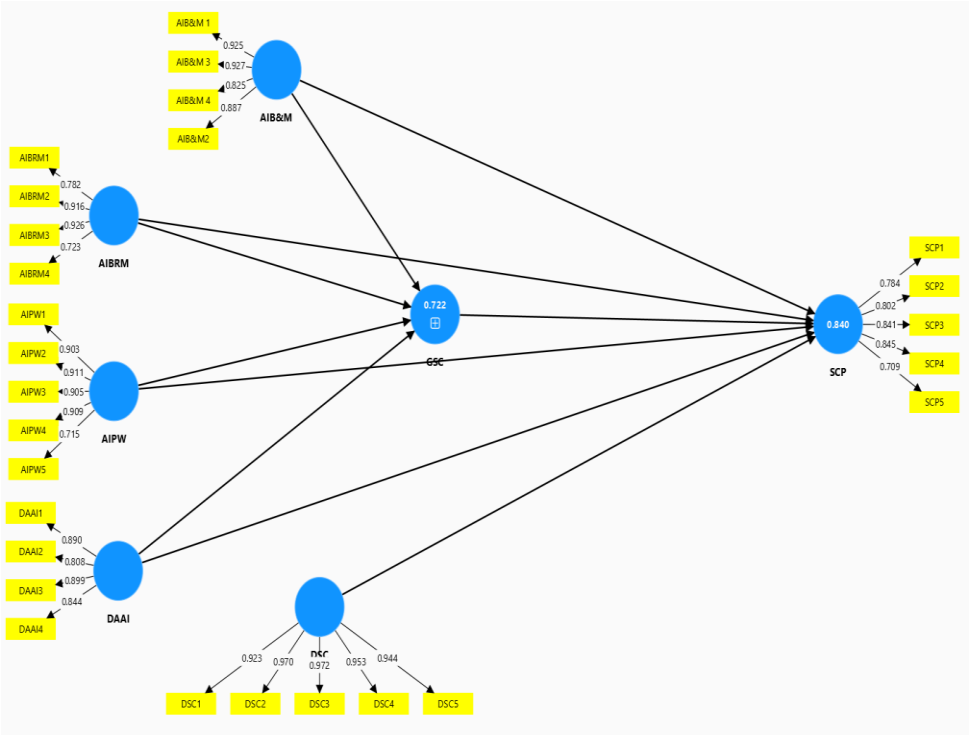

Figure 2: Factor loadings

Table 3: Discriminant Validity

Constructs	VIF	AIB&M	AIBRM	AIPW	DAAI	DSC	GSC	SCP
AIB&M	1.341	0.892						
AIBRM	1.231	0.409	0.841					
AIPW	1.892	0.414	0.488	0.872				
DAAI	1.341	0.093	0.114	0.129	0.861			
DSC	2.121	0.152	0.204	0.241	0.691	0.953		
GSC	1.823	0.183	0.244	0.249	0.432	0.381	0.873	
SCP		0.161	0.136	0.219	0.388	0.622	0.335	0.798

3.7 Hypothesis Results

This section predicted the results of the study hypothesis. For this purpose, the structural model was employed using the 5000 resampling technique in PLS-SEM (Figure 3). The structural model depicted results show that AI-based business and marketing significantly (β=0.512, p=0.002) and positively influence SCP. AI-based risk management also significantly influences SCP (β=0.438, p=0.004). The AI-powered workforce shows significantly (β=0.472, p=0.000) and positively influences SCP. Data analytics AI demonstrates a significant (β=0.398, p=0.001) and positive influence on SCP. The digital supply chain also positively (β=0.451, p=0.003) and significantly influences SCP. The green supply chain process also significantly (β=0.365, p=0.000) and positively influences on SCP.

Further indirect effect results showed that AI-based business and marketing also significantly (β=0.452, p=0.002) positively influence to SCP with the mediating influence of GSC. AI-based risk management significantly (β=0.387, p=0.001) and

positively influence on SCP with the mediating effect of the GSC. The AI-powered workforce significantly (β=0.417, p=0.000) and positively effect on SCP with the mediating effect of the GSC. Data analytics AI positively (β=0.402, p=0.000) and significantly influence on SCP with the mediating effect of GSC. Finally, the digital supply chain demonstrates significant (β=0.432, p=0.002) and positive influence on SCP with the mediating effect of GSC. The above results are predicted in Table.4 below,

Table 4: Hypothesis Results

Hypothesis	Original Sample	Standard Deviation	T-value	P-value	Decision
AIB&M → SCP	0.512	0.093	5.520	0.002	Accepted
AIBRM → SCP	0.438	0.087	5.030	0.004	Accepted
AIPW → SCP	0.472	0.076	6.211	0.000	Accepted
DAAI → SCP	0.398	0.108	3.692	0.001	Accepted
DSC → SCP	0.451	0.089	5.070	0.003	Accepted
GSC → SCP	0.365	0.062	5.892	0.000	Accepted
AIB&M → GSC->SCP	0.452	0.081	5.586	0.002	Accepted
AIBRM→ GSC->SCP	0.387	0.091	4.257	0.001	Accepted
AIPW→ GSC->SCP	0.417	0.069	6.035	0.000	Accepted
DAAI→ GSC->SCP	0.358	0.104	3.442	0.002	Accepted
DSC→ GSC->SCP	0.432	0.085	5.078	0.003	Accepted

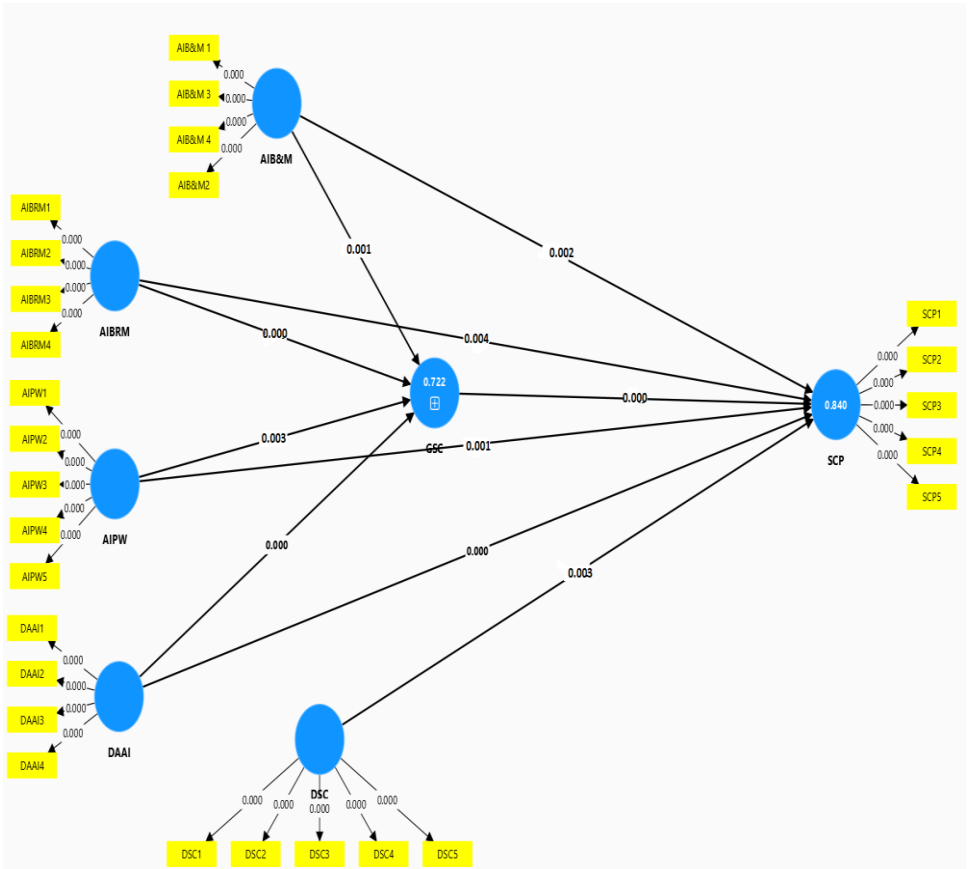

Figure 3: R square

4. Discussion

The research objective was to test the impact of artificial intelligence (AI) and digital supply chain (DSC) on supply chain performance (SCP) by the mediating effect of the green supply chain process (GSC) manufacturing companies in Saudi Arabia. The hypothesis results show that AI-based business and marketing positively and significantly influence on SCP of manufacturing companies in Saudi Arabia. These results highlighted the increasing role of artificial intelligence in driving business decisions. Therefore, it could be explained that Saudi manufacturers are adopting AI tools to optimize their marketing strategies, customer engagement, and demand forecasting. The ability to use AI for predictive analytics enables these companies to better match supply with fluctuating market demand, improving inventory management and reducing costs. The result is consistent with the study of (Belhadi et al., 2024; Wamba-Taguimdje et al., 2020), which found that AI in the manufacturing sector facilitates improved decision-making, thereby enhancing supply chain operations. These findings indicated that if the companies are focusing on AI-based business and marketing is important because the integration of AI technologies into business and marketing functions helps Saudi companies stay competitive by streamlining supply chain processes and enhancing customer satisfaction.

Further results also indicated that AI-based risk management a significantly and positively influence on SCP. This outcome outlines that AI-based risk management a critical factor in Saudi Arabia manufacturing companies which is considering the region's reliance on global trade and the volatility of oil prices. Saudi manufacturers face a unique set of risks, such as fluctuations in commodity prices, geopolitical instability, and supply chain disruptions. AI-driven risk management tools can help mitigate these risks by forecasting potential disruptions, enabling companies to take proactive measures. The results is consistent with the study of (Mittal & Panchal, 2023; Wong et al., 2024) where they found that the adoption of AI in risk management improves the resilience of Saudi companies by providing real-time risk assessments and automated responses. They also further concluded that AI risk management also enhances the overall stability of the supply chain, which is vital for manufacturers who need to maintain consistent production schedules despite external challenges. These findings shown that companies should focused on AI based risk management strategies because AI's predictive capabilities could help Saudi manufacturers identify potential disruptions early, reducing costly downtimes and ensuring smoother operations that could increase SCP and competitive advantage.

AI-powered workforce significantly and a positively influence on the SCP. The predicted results indicated that the integration of AI-powered workforce solutions has a strong positive effect on SCP on manufacturing companies, where automation is increasingly utilized to enhance productivity. With Saudi Arabia's Vision 2030 emphasizing technological innovation and economic diversification, the adoption of AI-driven automation systems is a key component of the country's industrial development strategy. AI technologies help in automating routine tasks, optimizing production schedules, and enhancing decision-making in real-time. The results is in line with the study of Kumar et al. (2024) where they also pointed out that use of AI in manufacturing reduces human error, increases operational efficiency, and allows workers to focus on higher-value tasks which increases the SCP. This finding shows that AI based powered workforce is important for the manufacturing companies because through enhancing workforce capabilities, AI not only improves

manufacturing performance but also helps companies maintain a competitive edge in an increasingly globalized market. In Saudi Arabia, where the manufacturing sector is expanding under Vision 2030, AI-powered solutions allow companies to scale production while reducing costs and improving overall SCP.

Results of this study indicated that big data analytics significantly and positively influence on SCP. These results show that in Saudi Arabian manufacturing sector, AI based big data analytics plays a crucial role in improving SCP, as it allows companies to optimize inventory management, demand forecasting, and resource allocation. With the growth of smart factories and the integration of IoT devices, data collection has become a central element of the manufacturing process. AI-driven data analytics tools help Saudi manufacturers make better, data-driven decisions by analyzing vast amounts of operational and market data. This leads to more accurate forecasting, better resource allocation, and reduced wastage. The results are supported by the study of (Belhadi et al., 2024; Rashid, Baloch, et al., 2024) who also emphasized the growing importance of AI in data analytics because it facilitates more efficient supply chain operations by improving inventory turnover and minimizing increasing stock. These findings enforced that AI data-driven is an important factor because it directly contributes to a more agile and responsive supply chain, which is critical for Saudi manufacturers striving to meet the demands of both local and international markets.

Current study findings explained that digital supply chain also positively and significantly influences on the SCP. These results show that the adoption of digital supply chain technologies in manufacturing companies has a significant positive impact on SCP. Digitalization through technologies such as cloud computing, IoT, and blockchain enables real-time tracking, enhanced communication, and data-driven decision-making, all of which are essential for modernizing supply chain operations. Saudi manufacturers are increasingly investing in digital solutions to improve transparency and traceability across their supply chains. The result is supported by the study of (Lee et al., 2024; Rashid, Rasheed, Ngah, et al., 2024) were also use digital tools to allow companies to track raw materials, monitor production processes, and ensure timely delivery of finished products. These technologies not only streamline operations but also provide the flexibility needed to respond quickly to market changes and external shocks. By adopting digital supply chain systems, Saudi manufacturing companies can achieve greater efficiency, reduce lead times, and increase customer satisfaction, leading to improved overall performance.

Current study results also reported direct significant and positive effect of green supply chain on SCP. These findings shown that the integration of green supply chain practices in Saudi manufacturing companies is gaining momentum, driven by both local environmental concerns and global sustainability trends. The Kingdom's commitment to Vision 2030 includes fostering sustainable business practices, and this extends to supply chain management. Green supply chain initiatives, such as energy-efficient logistics, waste reduction, and sustainable sourcing, have a positive impact on SCP by reducing operational costs and improving environmental outcomes. Saudi manufacturing companies are increasingly adopting green technologies, such as renewable energy for production processes and sustainable packaging solutions. The results is consistent with the study of Agyabeng-Mensah et al. (2024) who highlighted that a green supply chain not only leads to cost savings, enhanced brand reputation, and greater compliance with international environmental regulations which leads to improved SCP. These findings highlighted that manufacturing companies should focus

on green supply chain management because by adopting green practices, Saudi manufacturers could improve operational efficiency could contribute to the global sustainability agenda which is helping to enhance their SCP.

Further mediating effects show that the GSC partially mediated the relationship between all AI-based technologies and the SCP. These findings show that the combination of AI technologies with green supply chain practices significantly enhances SCP. The integration of AI technologies helps optimize demand forecasting and customer engagement, while the GSC ensures that operations are sustainable. Further authors also argued that when companies pay greater attention to technology optimization then the GSC increases. They also argued that a green supply chain increases the SCP. As this mediating effect has been tested first time, so this relationship could not be supported directly by the relevant studies. This relationship is further supported by the study of Belhadi et al. (2024) who also found that AI technologies increase the supply chain process of organizations. This research is also further supported by the study of Benzidia et al. (2021) which supported this view, showing that the synergy between AI and green practices leads to improved SCP. Further studies also showed that the digital supply chain positively and significantly affects to SCP of the manufacturing sector of Saudi Arabia. These findings enforced that the integration of AI and digital supply chain increases the GSC which leads to improvement that will not only help Saudi manufacturers optimize supply chain operations but also meet growing consumer and regulatory demands for sustainability.

5. Theoretical Implications

The study results have various theoretical contributions in the extant literature on artificial intelligence, digital supply chain, SCP with the mediating effect of GSC. As the first study to examine the combined effects of AI technologies, digital supply chain, and GSC on SCP, it extends existing models by demonstrating the significant role of AI-driven business and marketing, risk management, workforce automation, data analytics, and digital supply chain technologies in enhancing SCP. Further, this study also extended the theoretical understanding of how AI can transform supply chain management practices, especially when integrated with sustainability-driven practices, within emerging economies. Through showing the direct and mediating effects of AI-based practices on SCP, the study deepens our understanding of the dynamics at play in developing economies like Saudi Arabia, where technological and sustainability-driven transformations are central to industrial growth and economic diversification Furthermore, the findings suggest that AI, when combined with GSC, offers a comprehensive approach to improving supply chain resilience, efficiency, and sustainability an area that has not been explored in prior studies. The study findings could also help other researchers conduct their research with their extended model that could explore their new research area.

6. Managerial Implications

The study also has some managerial implications based on the study findings. For instance, the study could also provide actionable understandings for Saudi Arabian manufacturing companies aiming to enhance their supply chain performance through

AI and green supply chain integration. Managers in the Saudi manufacturing sector can leverage AI-based business strategies, risk management tools, workforce automation, and data analytics to optimize decision-making, mitigate risks, and improve overall operational efficiency. The findings further highlighted the necessity of embedding AI in the prevailing green supply chain process and the development of operational capabilities to meet the ever-increasing pressure on environmental responsibility. Particularly, Saudi producers should capitalize on these insights as they undertake their digital transformation journeys in pursuit of the Vision 2030 sustainable development goals. AI solutions will also enable managers to enhance their forecasts, minimize supply chain disruptions, and enhance customer interactions while improving environmental impacts and sustainability performance. This simultaneous focus on efficiency and sustainability gives Saudi manufacturers an edge in the international market regarding long-term sustainability in an era of global interdependence and environmental conservation. The study could also help practitioners pay greater attention to technology via investment that could increase the supply chain performance.

7. Limitations and Future Directions

This research has several limitations that should be noticed. The study only focused on the direct and the mediating effects while overlooking the possible moderating effects which would allow for a deeper and more advanced understanding of the relationships that were examined. In addition, the focus is on the manufacturing sector, excluding the service industry, and this may limit the ability to generalize the findings across other such domains with different attributes. Moreover, since the study relies on a quantitative approach to the survey, the study is unable to obtain the deeper contextual understanding that qualitatively driven strategies could have provided. As a way of overcoming these drawbacks, future studies should include moderating variables to determine contextual impacts, widen the scope to include service industries for more general relevance, and use of mixed approach in investigations to tell the quantitative story and in-depth qualitative stories such as interviews or case studies and in the end bring out a more rich and complex understanding. Lastly, the study overlooks the other countries that are developed in nature where this study's findings could be different from developing country. Therefore, future research could be explored in other developed countries to increase the generalizability of the study.

8. Conclusion

Supply chain performance is key to the success of any business, especially in manufacturing, where operational efficiency, cost reduction, and customer satisfaction are paramount. Therefore, Research empirical tested the impact of artificial intelligence adoption and digital supply chains on supply chain performance with the mediating effect of the green supply chain process of manufacturing companies in Saudi Arabia. For this purpose, cross-sectional collected data from 330 manufacturing firms' employees. Using self-administered questionnaires employing a convenient sampling technique. The results show that AI-based business and marketing, AI-based risk management, AI-based power workforce, and AI-based data

analytics have a positive and significant impact on supply chain performance. Digital supply chain and green supply chain process also positive and significant impact on supply chain performance. Further indirect effect results show that the green supply chain process is also partially mediated among AI-based factors, digital supply chain, and supply chain performance of Saudi Arabia firms. The study with these findings suggested that manufacturing companies should prioritize the integration of AI technologies and digital supply chain processes to enhance supply chain performance. Additionally, focusing on green supply chain practices can further amplify the benefits of AI and digital transformation that could increase the supply chain performance and competitive advantage of the organizations.

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Appendix: Measurement Scale

Big Data Analytics AI

1. Use of advanced analytical techniques (e.g., simulation, optimization, regression) to improve decision-making
2. Use of multiple data sources to improve decision-making
3. Use of data visualization techniques (e.g., dashboards) to assist decision-makers in understanding complex information
4. Deployment of dashboard applications/information in communication devices (e.g., smartphones, computers) of the GSC process

AI-based Risk Management

1. Our firm promotes AI tools to simulate different project scenarios and assess their associated risks.
2. Our firm executed AI-powered systems to monitor project progress and identify potential safety hazards.
3. Our firm use AI-powered analytics to predict and mitigate cost overruns.
5. Our firm use AI risk management tools project schedules and resource allocation.
6. Our firm allocates budget for implementing AI-driven risk management solutions.

Digital Supply Chain

1. The digital supply chain increased its SCM flexibility.
2. Digital supply chain lower the inventory and warehousing costs.
3. A digital supply chain lowers the supply chain risk.
4. Digital supply chains lower the supply chain complexity.
5. Digital supply chains lower the transport and logistics administration costs

Supply Chain Performance

Based On the Most Recent Three Years Performance, Our Company Has …

1. Improve sales.
2. Improve order fill rate.
3. Improve manufacturing lead time.
4. Improve the quality of the product.
5. Improve reliability on supply chain delivery including lower shipping errors.

AI-Based Business and Marketing

1. Is data analytics help AI adoption in manufacturing?
2. Is AI technology help financial planning in Manufacturing?
3. Is AI technology influence business innovation in manufacturing?
4. Respond to competitor strategy Is AI technology helping in quick response to the competitors of manufacturing?

Artificial Intelligence-Based Workforce Management

1. Does AI capability help the AI-powered in Manufacturing?

2. Is government support and regulation help AI-powered WFM in Manufacturing?
3. Does automated scheduling help the AI-powered in Manufacturing?
4. Digital skills: Are digital skills of employers helping AI-powered in Manufacturing?
5. Chatbots: Are the chatbots helping the AI adoption for manufacturing?

Green Supply Chain Process

1. Supplier selection on environmental criteria
2. Advising suppliers on environmental technical issues
3. Engaging suppliers in product eco-design & development
4. Appraising environmental performance of the suppliers