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Impact of Adoption of Artificial Intelligence in Sustainable Supply Chain Performance in Manufacturing Organization of Pakistan: The Mediating Role of Supply Chain Integration

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ABSTRACT

According to the resource-based view, the study examines the adoption of artificial intelligence to enhance sustainable supply chain performance in manufacturing organizations in Pakistan. More specifically, this study also determines the mediating role of supply chain integration. The study is based on a quantitative, closed-ended questionnaire. This questionnaire is based on a sample of 310 from a manufacturing organization in Lahore, Pakistan. The study analysis was conducted using SPSS software. The study findings suggested that the adoption of artificial intelligence has a significant positive impact on sustainable supply chain performance in manufacturing organizations. Furthermore, supply chain integration partially mediates the relationship between the adoption of artificial intelligence and sustainable supply chain performance. The study's findings are helpful to policymakers and business owners in implementing the latest technologies to achieve efficient results.

Introduction

Before the industrial revolution, manufacturing was done in a way that might have been a more effective mass-production system (Dalenogare et al., 2018). Consumer expectations and demands have changed over the years, including a desire for personalized products. As a result, production sectors have become increasingly complex and have had to meet more stringent manufacturing standards (Helmrich, 2015). At the same time, innovations such as AI have opened new opportunities for businesses by making their operations easier and giving them access to global customers (Brodner, 2018). The use of AI in the workplace is quickly becoming popular in manufacturing and in many other overseas company settings (Hofmann & Rusch, 2017). As well as discussing AI's use in the advancement of economies in developing countries, the "Hannover Messe Industries Fair" held in 2011 addressed the topic of the impact of integrating Cyber-

Physical Systems (CPSs) into business models, demonstrating a potential for AI-type disruptive change within the industrial automation sector (Sriram & Vinodh, 2021). The major focus of this research area is on collecting real-time data across all areas to improve decision-making for all stakeholders and reduce costs. AI-based setting and aim of digitizing manufacturing processes to increase competitiveness in this environment (Contreras et al., 2024; Latif et al., 2025). There are a large number of emerging digital technologies that are being used to support this digitization and include, but are not limited to, IoT, IoE, CPS, RFID, ERP, cloud-based manufacturing, BD analytics, autonomous robots, and simulation (Gibson et al., 2021; Safavi Jahromi & Ghazinoory, 2024). The importance of AI within manufacturing has positive outcomes. According to Raj et al. (2020) and McKinsey (2016), productivity is expected to increase by 55% and profit margins by 15% when advanced technology is used in manufacturing processes. The level of communication among manufacturing machines and employees working in manufacturing processes has also improved with increasing digitalization, resulting in better processes, enhanced efficiency, and less downtime (Salman et al., 2023). In the increasingly complex and personalized digital environments of manufacturing, collaboration between humans and machines is occurring to meet specific customer needs (Rahman et al., 2025). The digitalization of manufacturing processes has created faster, more efficient, and more effective ways to produce final products and deliver them to end customers (Hernandez et al., 2020). The digitalization and implementation of AI in the production system are changing the way global manufacturing industries operate, and this technique is better than traditional production techniques. The digitalization of production processes is now becoming greener and more environmentally friendly, providing a competitive advantage to the manufacturing industry (Gillani et al., 2020; Aziz et al., 2025). The implementation of AI is expected to continue to provide benefits through the modularization of production processes, leveraging operating systems such as AI, IoT, ERP, CPS, and other software systems to improve the supply chain and product lifecycle management (Galati & Bigliardi, 2019). The effects of digitalization, such as AI, in operational activities in production seem very efficient in new product development. Moreover, this has computerized modelling and the monitoring and control of the inputs used by the production process, as well as monitoring and controlling the sales and distribution of the final products within the organization or between departments that include healthcare, agriculture, construction, food and manufacturing departments (Stefanini & Vignali, 2024; Latif et al., 2025). In this regard, the digitalization of the production process and the application of AI to it represent a contemporary perspective on the circular economy, sustainable economic development, the productivity of human investment in the manufacturing sector, and performance (Rajput & Singh, 2019). Furthermore, the digital technologies implemented and enhanced automated, advanced scheduling of maintenance and production processes, resulting in a significant reduction in maintenance costs. As a result of optimizing equipment performance, the quantity of final products produced increased (Aljanabi & Ghafour, 2021; Ibrahim et al., 2025). The digitalization of production has brought many effects beyond those described above in the manufacturing area. Those effects have enhanced the process and have increased focus on improving operational activities throughout all phases of the operation. A global survey conducted by the World Economic Forum (2020) reported that 84% of the respondents were interested in utilizing digital work styles, such as telecommuting and video conferencing (Schwab & Zahidi, 2020). The AI is implemented in line with sustainable business practices (Bag et al., 2023), helping it achieve this. AI is also used by companies to assess their performance on a long-term basis (Agyabeng-Mensah & Tang, 2021). More than ever before, technologies such as AI and IoT are changing the supply chain (SC) as we know it today, increasing productivity and efficiency for businesses (Meng et al., 2021). Platforms are being created which will eventually replace traditional SC's (Zhou et al., 2022). Social media, mobile networks, and other e-commerce type digital platforms which focus on the needs of the customer, help consumers create informed purchasing decisions, and so far, the technology which creates these types of digital platforms is

also being utilized to transform traditional SCs into modern digital systems, allowing people to view more information, collaborate better, be more efficient, and react quicker (Geodis, 2022). Transparency technologies are becoming necessary tools for exchanging information with people to enhance supply chain integration (Raymond et al., 2016). In the above discussion, the following adoption of artificial intelligence has a positive influence on sustainable supply chain performance. Moreover, supply chain integration positively influences the adoption of artificial intelligence and sustainable supply chain performance.

Literature Review and Hypotheses

Adoption of Artificial Intelligence and Sustainable Supply Chain Performance:

This (RBT) is a good way for a manager to reflect on how he/she fits into the strategic management process. Managers have long relied on RBT as a resource-based identification to determine resources that would provide for an organization with a "sustainable competitive advantage". The RBT also offers a very practical outline for analyzing and forecasting a firm's fundamental competitive advantage (Utami & Alamanos, 2023). Every organization requires an effective, lasting process to sustain success over time. Therefore, organizations that utilize artificial intelligence can generate more goods at lower cost and deliver improved service (Dash et al., 2019). In addition to having a noteworthy influence on the SCM of Saudi organizations, the use of artificial intelligence provides several additional benefits, including higher quality standards, greater efficiency, greater adaptability, and increased productivity (Alsharidah & Alazzawi, 2020). There has been a recent surge in interest in tools utilizing AI among researchers and practitioners. Utilizing AI-based tools is important for organizations to collaborate in solving environmental problems worldwide (Benzidia et al., 2021). The application of artificial intelligence in the "food industry" is beneficial for both consumers and the community, in addition to fostering greater awareness of topics such as openness, explanation, ease of use, and accountability (Manning et al., 2022). The usage of these technologies can make it extra responsive and more efficient. In addition, the ability to utilize data diversity for sustainable SC performance makes the processes involved faster, more flexible, and more productive (Dubey et al., 2022). Utilizing artificial intelligence can provide several useful capabilities that assist with customer, supplier, and internal organizational operations, thereby supporting longer-term performance (De Vass et al., 2018). Utilizing artificial intelligence can improve the effectiveness of the value supply chain system (Rejeb et al., 2019). Furthermore, utilizing AI can enhance the effectiveness of data exchange, interaction, and monitoring, thereby improving compatibility and long-term performance (Gnimpieba et al., 2015). An additional study indicates that artificial intelligence increases trust and safety, reduces costs, operates efficiently, reduces waste, and changes how we view sustainable performance (Queiroz et al., 2020). Furthermore, the implementation of AI is crucial to achieving sustainability (Maheshwari et al., 2021). The optimistic effects of AI on the performance of sustainable supply chains are evident (Bag et al., 2020). In addition, artificial intelligence can enable organizations to develop supply chain reports and enhance long-term performance (Nicoletti & Appolloni, 2024; Latif, 2025). This study advocates and highlights the advantages of utilizing AI for collaboration within supply chains, for managing environmental uncertainty, and for enhancing logistics resilience and sustainable performance (Wang & Pan, 2022). AI has a positive impact on the performance of the global supply chain system and has enhanced financial and operational outcomes for sustainable performance (Dubey et al., 2021). This study states that AI significantly impacts procedural features of the SC, such as information dissemination and integration, and enhances the ability to mitigate risks (Nayal et al., 2022). Artificial intelligence-based solutions that ensure precision, speed and consistency in the distribution of products for sustained performance (Goodarzian et al., 2023). AI and other advanced technologies are making supply chain activities more flexible, efficient, and open. In addition, the risk is associated with

disruptions to logistical networks, demand volatility and sustainability challenges (Chen et al., 2023). Therefore, sustainable AI technology can improve performance (Yadav et al., 2021).

Hypothesis H1: The adoption of artificial intelligence has positive relation with sustainable supply chain performance.

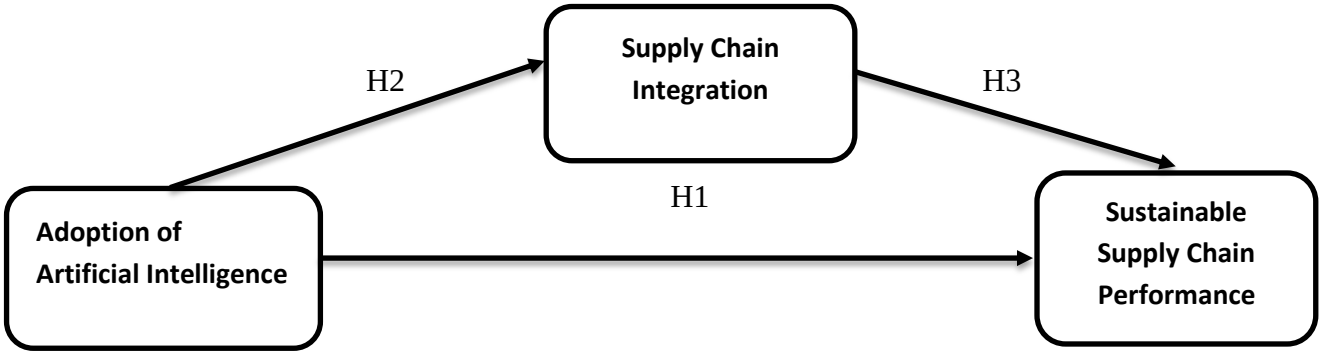
Supply Chian Integration Role as Mediator:

Sustainability is a challenge that Artificial Intelligence (AI) has been able to meet (Zhen et al., 2023). The AI is implemented in line with sustainable business practices (Bag et al., 2023), helping it achieve this. AI is also used by companies to assess their performance on a long-term basis (Agyabeng-Mensah & Tang, 2021). More than ever before, technologies such as AI and IoT are changing the supply chain (SC) as we know it today, increasing productivity and efficiency for businesses (Meng et al., 2021). Platforms are being created which will eventually replace traditional SC's (Zhou et al., 2022). Social media, mobile networks, and other e-commerce type digital platforms which focus on the needs of the customer, help consumers create informed purchasing decisions, and so far, the technology which creates these types of digital platforms is also being utilized to transform traditional SCs into modern digital systems, allowing people to view more information, collaborate better, be more efficient, and react quicker (Geodis, 2022). Transparency technologies are becoming necessary tools for exchanging information with people to enhance supply chain integration (Raymond et al., 2016). The fast flow of advanced data during SC. (Bjerge et al., 2016), such as an effective distribution process (Smit, A.D, 2005). The success depends on decision-makers in operational activities (Lal, 2008). According to Thomas & Kopczak (2007), systemic vulnerabilities in information systems are caused by poor systems and unskilled labor. Bealt et al. (2016) say that partners have to work harder than they need to and don't share information well because they don't have the right IT infrastructure. IT infrastructure can also impede communication between customers and management, as mistakes in this area can be costly (Masoud, 2022). There are several viewpoints on SCI (Opara, 2003). The study indicates integration is enhanced over advanced technologies. The existing literature shows that they do not effectively integrate or connect the many technologies needed to achieve better results. indicates that SCT may arise from developing technologies, yet studies need a cohesive framework to integrate and connect these many technologies of traceability and transparency (Opara, 2003). The objective of SCI is to facilitate information sharing, coordination, and organizational linkages. The primary function of AI is to enhance an organization’s efficiency (Hanaysha & Alzoubi, 2022). Digital technologies, such as AI, drive both inter-organizational and intra-organizational transactions. DT, like AI and all SC systems, had to provide reliable information for valuable data-driven decisions. For instance, blockchain technology might make data immutable and irreversible, so it can't be changed without the permission of stakeholders (Stroumpoulis & Kopanaki, 2022). This improves integration, and ERP is used for information flow. Blockchain technology is used to get real-time inventory, and operations are integrated in many areas.

Hypothesis H2: The adoption of artificial intelligence has positive relation with supply chain integration.

Hypothesis H3: The supply chain integration has positive relation sustainable supply chain performance

Hypothesis H4: Supply chain integration has positive mediating role among adoption of artificial intelligence and sustainable supply chain performance.



Conceptual Framework

Methodology

The current study examines the impact of adopting artificial intelligence on sustainable supply chain performance in manufacturing organizations in Lahore, Pakistan. It has a mediating role of supply chain integration. The methodological approaches and analytical techniques are derived from past studies on multidisciplinary papers conducted by (F, Saddique & N, Mushtaq et al., 2020 to 2026). The questionnaires were given to employees of various manufacturing companies in Lahore. At first, 500 questionnaires were sent out, but only 310 were returned. The total questionnaire comprises 17 questions, covering demographics, adoption of artificial intelligence, sustainable supply chain performance, and supply chain integration. Demographic information that includes variables such as gender, age, level of education, and experience.

Table 3.1: Variables, No. of Items, Sample Items and Reference:

Variable	Items	Reference
Artificial Intelligence	3	Chatterjee et al. (2023)
Supply Chain Integration	5	Lee, S. (2021).
Sustainable Supply Chain Performance	5	Ma et al. (2022).

Table 3.2: Sample Distribution:

	Characters	F	%
Gender	Male	224	72.3
	Female	86	27.7
	Total	310	100
Ages	Below than 25	49	15.8
	26-40	156	50.3
	41-55	89	28.7
	Above 55	16	5.1
Qualification	Matric	27	8.7
	Intermediate	83	35.5
	Graduation	112	36.1
	Post Graduate	88	28.6
Experience	Less One Year	61	19.7
	From 1 to 5 years	56	18.1
	From 6 to 10 Years	164	52.9
	Above 10 years	29	9.4

Explanation: According to Table 3.2 above, the total number of respondents to the questionnaires was 500, of which 310 were collected; 224 were male (72.3%), and 68 were female (27.7%). The

respondents' age was classified into five groups. The majority of respondents were between the ages of 26 and 40 years (156, 50.3%), as shown in the table; 16 (5.1%) were above 55. Based on the qualification, respondents were divided its four groups: the majority were graduates from university 112 (71.6%), and a small number were matric 27 (8.7%). Based on experience, it's categorized into four categories. The majority of respondents have 6 to 10 years of experience, 164 (52.9%), and the minority have more than ten years of experience, 29 (9.4%)

Table 3.3: Reliability Analysis:

Variable	No of Items	Cronbach's Alpha
Artificial Intelligence Adoption	3	0.901
Supply Chain Integration	5	0.937
Sustainable Supply Chain Performance	5	0.937

Explanation: The reliability test of each scale was examined using Cronbach's alpha. See table #3.3. All the above values are higher than 0.70, which indicates that the measurements were accurate and acceptable enough for future research.

Correlation Analysis

Pearson Correlation analysis is used to assess stable associations and examine the dependency between two variables. Estimates of connectivity range from negative 1 to positive 1. They consider -0.5 to -0.3 and 0.3 to 0.5 as strong and high associations; -0.3 to -0.1 and 0.1 or 0.3 are low/delicate associations. When the estimate's connection is zero, it means there is no link between the factors.

Table 3.4: Correlation Analysis

Variables	1	2	3	4	5	6
1. Gender	1					
2. Ages	-0.065	1				
3. Qualification	-0.049	0.88	1			
4. Experience	0.050	0.10	-0.199	1		
5. Artificial Intelligence	0.038	0.60	0.190	-0.019	1	
6. Supply Chain Integration	0.022	0.54	0.011	0.090	0.397**	1
7. Sustainable SC Performance	0.054	0.030	0.023	-.139	0.343**	0.517**

** Correlation is Shown Significant at 0.01 level, *Correlation is Significant at 0.05 level

Explanation: Table 3.4 illustrates the associations among the factors in this study. Artificial intelligence is significantly and moderately correlated with supply chain integration (r=0.397, p=0.00), and artificial intelligence is moderately and significantly correlated with sustainable supply chain performance (r=0.343, p=.000). In addition, the association between supply chain integration and sustainable supply chain performance is strong and statistically significant (r = 0.517, p =.000).

Regression Analysis

Table 3.5.1. Model between artificial intelligence and sustainable supply chain performance

Variable	R^2	B	t	sig
Artificial intelligence	0.117	0.248	6.40	0.000

Dependent Variable: SSC Performance* $p < 0.05$.

Explanation: Table 3.5.1 demonstrates the basic regression analysis performed to determine the impact of artificial intelligence on sustainable supply chain performance. The model is fit since the ANOVA sig value is 0.00 < 0.05. The R-squared value of 0.117 indicates that a one-unit change in artificial intelligence has resulted in a 11.7% difference in sustainable supply chain performance. The coefficient's p-value is 0.00, which is less than 0.05, indicating a significant association between them. The value of B is 0.248, indicating that artificial intelligence affects sustainable supply chain performance. Hence, Hypothesis 1 is supported.

Table 3.5.2. Model between artificial intelligence and supply chain integration.

Variable	R^2	B	t	sig
Artificial Intelligence	0.157	0.512	7.586	0.000

Dependent variable: Supply Chain Integration, *p < 0.05.

Explanation: Table # 3.5.2. demonstrates the basic regression analysis performed to determine the impact of artificial intelligence on supply chain integration. The model is fit since the ANOVA sig value is 0.00 < 0.05. The R-squared value of 0.157 indicates that a one-unit change in artificial intelligence results in a 15.7% change in supply chain integration. The coefficient's p-value is 0.00, which is less than 0.05, indicating a significant association between them. The value of B is 0.512, indicating that artificial intelligence affects supply chain integration. Hence, Hypothesis 2 is supported.

Table 3.5.3. Model between supply chain integration and sustainable supply chain performance

Variable	R^2	B	t	sig
Supply Chain Integration	0.267	0.483	10.598	0.000

Dependent Variable: Sustainable SC Performance, *p < 0.05.

Explanation: Table 3.5.3 demonstrates the basic regression analysis performed to determine the impact of supply chain integration on sustainable supply chain performance. The model is fit since the ANOVA sig value is 0.00 < 0.05. The R-squared value of 0.267 indicates that a one-unit change in supply chain integration results in a 26.7% change in sustainable supply chain performance. The coefficient's p-value is 0.00, which is less than 0.05, indicating a significant association between them. The value of B is 0.483, indicating that supply chain integration affects sustainable supply chain performance. Hence, Hypothesis 3 is supported.

Mediation Analysis:

Table 3.5.4: Mediation analysis using through Bootstrap

Relationships	*β*	*P*	Bootstraps @ 95%		Hypotheses
			LL	UL	
AI→SCI→SSCP					
Direct effect	0.118	***	0.043	0.202	
Indirect effect	0.423	***	0.325	0.540	

Note: AI=Artificial Intelligence, SCI= Supply Chain Integration, SSCP= Sustainable Supply Chain Performance, ***p<0.01

Explanation: The mediating variable hypothesis was evaluated using 1000 bootstraps with a 95% confidence interval and upper and lower limits established. The role of supply chain integration as a mediator associated between artificial intelligence and sustainable supply chain performance, the indirect effect (0.423, LL = 0.325, UL = 0.540, P=0.01) was smaller than the direct consequence (β = 0.118, P 0.01), and there was no "0" value between upper and lower limits, therefore, Hypothesis

H5 is accepted. Supply chain integration is shown to partially mediate the association between artificial intelligence and sustainable supply chain performance.

Discussion

Every organization requires an effective, lasting process to sustain success over time. Therefore, organizations that utilize artificial intelligence can generate more goods at lower cost and deliver improved service (Dash et al., 2019). In addition to having a significant influence on the SCM of Saudi organizations, the use of artificial intelligence provides several additional benefits, including higher quality standards, greater efficiency, greater adaptability, and increased productivity (Alsharidah & Alazzawi, 2020). There has been a recent surge of interest in tools utilizing artificial intelligence among researchers and practitioners. In addition, utilizing AI-based tools is important for organizations to collaborate in solving environmental problems worldwide (Benzidia et al., 2021). The use of artificial intelligence in the "food industry" benefits both consumers and the community, while also fostering greater awareness of topics such as openness, transparency, ease of use, and accountability (Manning et al., 2022). The use of AI technologies can make it more responsive, reliable, and efficient. In addition, the ability to utilize data diversity for sustainable supply chain performance makes the processes involved faster, more flexible, and more productive (Dubey et al., 2022). Utilizing artificial intelligence can provide several useful capabilities that assist with customer, supplier, and internal organizational operations, thereby supporting longer-term performance (De Vass et al., 2018). Utilizing artificial intelligence can improve the effectiveness of the value supply chain system (Rejeb et al., 2019). Furthermore, utilizing artificial intelligence can enhance the effectiveness of data exchange, interaction, and monitoring, thereby improving compatibility and long-term performance (Gnimpieba et al., 2015). An additional study indicates that artificial intelligence increases trust and safety, reduces costs, operates efficiently, reduces waste, and changes how we view sustainable performance (Queiroz et al., 2020). Furthermore, the implementation of AI is crucial to achieving sustainability in logistics and inventory management (Maheshwari et al., 2021). The positive effects of advanced technologies, including AI, on the performance of supply chain integration on sustainable supply chains are evident (Bag et al., 2020). In addition, artificial intelligence can enable organizations to develop supply chain reports and enhance long-term performance through supply chain integration (Nicoletti & Appolloni, 2024). Sustainability is a challenge that Artificial Intelligence (AI) has been able to meet (Zhen et al., 2023). The use of AI in logistics, for example, and the implementation of sustainable business practices with supply chain integration (Bag et al., 2023), help it to achieve this. AI is also used by companies to assess their performance on a longer-term basis with supply chain integration (Agyabeng-Mensah & Tang, 2021). More than ever before, technologies such as AI and IoT are changing the supply chain (SC) as we know it today, increasing productivity and efficiency for businesses (Meng et al., 2021). Platforms are being created which will eventually replace traditional SC's (Zhou et al., 2022). Social media, mobile networks, and other e-commerce type digital platforms which focus on the needs of the customer, help consumers create informed purchasing decisions, and so far, the technology which creates these types of digital platforms is also being utilized to transform traditional SCs into modern digital systems, allowing people to view more information, collaborate better, be more efficient, and react quicker and enhance with supply chain integration (Geodis, 2022). The above discussion shows that adopting artificial intelligence has a positive impact on sustainable supply chain performance. Furthermore, supply chain integration partially mediates the relationship between artificial intelligence and sustainable supply chain performance. So, in short, all the study hypotheses are accepted.

Theoretical Contributions

This research helps us better understand how artificial intelligence impacts sustainable supply chain performance. This research examined the direct and indirect association of supply chain integration in between artificial intelligence and sustainable supply chain performance in the manufacturing organization of Pakistan. Previous research shows that digital technologies have a positive impact on supply chain performance, and supply chain integration is now also used as a mediator sustainability and artificial intelligence among them. The mentioned theories were offered and tested in Pakistan's cultures to better understand. As a result, we tested our hypothesized model by selecting participants from a manufacturing organization in Pakistan.

Practical Implications

The findings have several significant implications. This demonstrated that artificial intelligence improves technological advancement in Pakistani organizations. Second, this study's results show that adopting artificial intelligence directly influences sustainable supply chain performance through supply chain integration. In addition, it will allow policymakers to assess the direct and indirect impacts of AI on organizational performance. Third, leadership effectiveness is maximized through technological advancements, with support for participation and fair outcomes in the workplace. As a result, practical management implications have been provided that may help to address newly developed requirements in today's organizational development. Fourthly, this may help the investor to make a decision efficiently for business.

Study Limitations and Future Directions

Limitations have existed in this present study. Initially, our study used data from a single source, even though we used a questionnaire with a small sample. Second, our data came from manufacturing companies. The more variables are used for future studies. Finally, we obtained our sample from Pakistan.

Conclusions

This research examines how artificial intelligence adoption impacts sustainable supply chain performance. It also aimed to determine the implications of mediating roles of supply chain integration in manufacturing organizations. Our research supports the proposed hypothesis that artificial intelligence has a positive impact on sustainable supply chain performance. Furthermore, supply chain integration partially mediates the relationship between artificial intelligence and sustainable supply chain performance. This study is helpful for business owner to invest in technology to achieve better business outcomes.

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