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Unlock the Sustainable Supply Chain Performance Through Artificial Intelligence and Moderator Digital Culture in Pakistan Context

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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 moderator role of digital culture. The study is based on a quantitative, closed-ended questionnaire. This questionnaire is based on a sample of 292 from a manufacturing organization in 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, digital culture has positive 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.



1. 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). There are a large number of emerging digital technologies that are being used to support this digitization and include, but are not limited to 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). 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). 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). 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 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). Digital culture influences the use of digital technologies in different ways (Martínez et al., 2020). Some studies say that digital

technologies have only a small effect on a business's performance, and that for a significant improvement to occur, there need to be organizational factors like DC (Wiengarten et al., 2013). Additionally, Melville et al. (2004) contend that company DC influences information technology throughout the value-creation process. In a digitalized world, digital culture refers to a company's openness to using and accepting digital technology (Blatz et al., 2018). If the company uses digital technologies like AI, it has a supportive digital culture (Witschel et al., 2019). In the above discussion, the following adoption of artificial intelligence has a positive influence on sustainable supply chain performance. Moreover, digital culture positively moderate influences on adoption of artificial intelligence and sustainable supply chain performance.

2. Literature Review and Hypotheses

2.1 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). 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

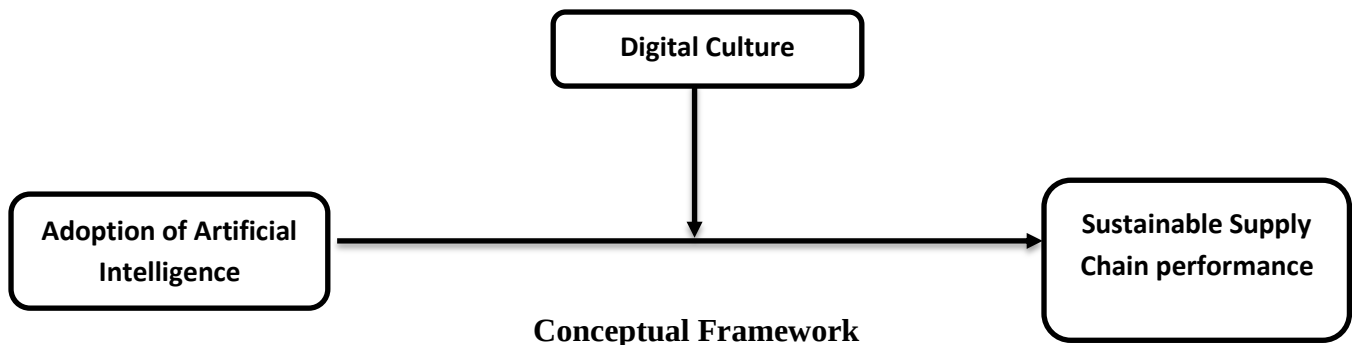
that ensure precision, speed and consistency in the distribution of products for sustained performance (Goodarzian et al., 2023). AI and other advanced technologies are making supply chain activities more flexible, efficient, and open. In addition, the risk is associated with disruptions to logistical 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.

2.2 Moderator Role of Digital Culture:

Digital culture influences the use of digital technologies in different ways (Martínez et al., 2020). Some studies say that digital technologies have only a small effect on a business's performance, and that for a significant improvement to occur, there need to be organizational factors like DC (Wiengarten et al., 2013). Additionally, Melville et al. (2004) contend that company DC influences information technology throughout the value-creation process. In a digitalized world, digital culture refers to a company's openness to using and accepting digital technology (Blatz et al., 2018). If the company uses digital technologies like AI, it has a supportive digital culture (Witschel et al., 2019). Prior studies demonstrate that digital culture influences the impact of advanced technologies on SSCP (Yu et al., 2021). Moreover, DC directly influences performance (Martínez et al., 2021), and it influences the operation and adoption of digital technologies such as AI (Liu et al., 2010). The research posits that the impact of DT is associated with the DC within such an organization that wants progress. It is well recognized in the field of management that culture plays an important role in supporting technological transformation and innovation. Within the realm of digitalization, digital culture represents one key area that may affect the digital drive, digital adoption and innovation performance. Digital culture is defined by Chen et al. (2022) as a composite of organizational values, behavioral norms, structural design, managerial styles, and communication processes that support individuals' ability to adopt AI technologies. Organizational commitment to full-scale incorporation of AI supports both digital adoption and digital drive-in organizations that possess strong digital cultures. Both DT and KBT are cited as providing theoretical justification for digital culture as a moderating variable in the association of digital technologies adoption, digital drive, and innovativeness. As DT, the social systems within an organization will affect how innovation is adopted (Rogers, 2020). Thus, digital culture serves as a social framework that can enable the adoption of digital technologies, such as AI. KBT highlights the rank of an organization's setting in supporting the making and use of knowledge (Grant, 1996). Digital culture influences how knowledge is shared, utilized, and integrated throughout an organization.

Hypothesis H2: Digital culture has significant positive moderator role among the adoption of artificial intelligence and sustainable supply chain performance.



3. Methodology

The current study examines the impact of adopting artificial intelligence on sustainable supply chain performance in manufacturing organizations in Pakistan. It has a moderating role digital culture. 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 Pakistan at first, 500 questionnaires were sent out, but only 292 were returned. The total questionnaire comprises 16 questions, covering demographics, adoption of artificial intelligence, sustainable supply chain performance, and digital culture. 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
Adoption of Artificial Intelligence	3	Chatterjee et al. (2023)
Sustainable Supply Chain Performance	5	Ma et al. (2022)
Digital Culture	4	Malewska et al. (2024)

Table: 3.2. Sample Distribution:

	Characters	F	%
Gender	Male	212	72.6
	Female	80	27.4
	Total	292	100
Ages	Less Than 25 Years	45	41.2
	From 26 to 40	122	27.7
	From 40 to 55	97	4.9
	Above 55	28	5.3
	Total	19	100
Qualification	Matric	22	7.5
	Intermediate	72	24.7
	Graduate	110	37.7
	Post Graduate	88	30.1
	Total	292	100
Experience	Below One Year	61	20.9
	1 - 5 years	51	17.5
	6-10 Years	151	51.7
	Above 10 years	29	9.9

Explanation: According to Table 3.2 above, the total number of respondents to the questionnaires was 500, of which 292 were collected; 212 were male (72.6%), and 80 were female (27.4%). The respondents' age was classified into five groups. The majority of respondents were between the ages of 26 and 40 years (112, 27.7%), as shown in the table; 19 (5.3%) were above 55. Based on the qualification, respondents were divided its four groups: the majority were graduates from university 110 (37.7%), and a small number were matric 22 (7.5%). Based on experience, it's

categorized into four categories. The majority of respondents have 6 to 10 years of experience, 151 (51.7%), and the minority have more than ten years of experience, 29 (9.9%)

Table#, 3.3: Reliability Analysis:

Variable	No of Items	Cronbach's Alpha
Adoption of Artificial Intelligence	3	0.90
Sustainable Supply Chain Performance	5	0.88
Digital Culture	4	0.87

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 Table:

Variables	1	2	3	4	5	6
1. Gender	1					
2. Ages	-0.59	1				
3. Qualification	-0.45	0.050	1			
4. Experience	0.07	0.018	0.192**	1		
5. Artificial Intelligence	0.34	0.54	0.172**	-0.28	1	
6. Sustainable Supply Chain Performance	0.049	0.022	0.28	-.145	0.367**	1
7. Digital Culture	-.078	0.063	-0.016	0.007	.478**	0.225**

** 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 sustainable supply chain performance ($r=0.367$, $p=0.00$), and artificial intelligence is moderately and significantly correlated with digital culture ($r=0.478$, $p=.000$). In addition, the association between sustainable supply chain performance and digital culture is moderate and statistically significant ($r = 0.225$, $p =.000$).

3.5 Regression Analysis

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

Variable	R ²	B	t	sig
Artificial intelligence	0.115	0.236	7.89	0.000

Dependent Variable: Sustainable Supply Chain 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 0.115 indicates that a one-unit change in artificial intelligence has resulted in a 11.5% 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 0.236, indicating that artificial intelligence affects sustainable supply chain performance. Hence, Hypothesis 1 is supported.

Table 3.5: Moderation-Analysis

Variables	<i>B</i>	<i>R</i> ²	<i>P</i>
Adoption of Artificial Intelligence (AAI)	0.276	0.136	***
Digital Culture (DC)	0.171	0.051	***
AAI x DC	0.045	0.111	***

Note: Dependent Variable = Sustainable Supply Chain Performance

Explanation: In Table 3.5. While conducting moderation analysis, we found that artificial intelligence has significantly affected sustainable supply chain performance ($\beta = 0.276$, $p < 0.01$), with a proportion of variance (R^2) = 0.136. Similarly, the moderator digital culture significantly affects sustainable supply chain performance ($\beta = 0.171$, $p < 0.01$), with a proportion of variance (R^2) of 0.051. The interaction term (artificial intelligence x digital culture) is also statistically significant ($\beta = 0.045$, $p < 0.01$), indicating that digital culture moderates the association between artificial intelligence and sustainable supply chain performance. Therefore, our hypothesis H2 is also accepted.

4. 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). Sustainability is a challenge that Artificial Intelligence (AI) has been able to meet (Zhen et al., 2023). AI is also used by companies to assess their performance through digital culture (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). Digital culture influences the use of digital technologies in different ways (Martínez et al., 2020). Some studies say that digital technologies have only a small effect on a business's performance, and that for a significant improvement to occur, there need to be organizational factors like DC (Wiengarten et al., 2013). Additionally, Melville et al. (2004) contend that company DC influences information technology throughout the value-creation process. In a digitalized world, digital culture refers to a company's openness to using and accepting digital technology (Blatz et al., 2018). If the company uses digital technologies like AI, it has a supportive digital culture (Witschel et al., 2019). Prior studies demonstrate that digital culture influences the impact of advanced technologies on SSCP (Yu et al., 2021). Moreover, DC directly influences performance (Martínez et al., 2021), and it influences the operation and adoption of digital technologies such as AI (Liu et al., 2010). The above discussion shows that adopting artificial intelligence has a positive impact on sustainable supply chain performance. Furthermore, Digital culture has positively moderated the relationship between artificial intelligence and sustainable supply chain performance. So, in short, all the study hypotheses are accepted.

4.1 Theoretical Contributions

This research helps us better understand how artificial intelligence impacts sustainable supply chain performance. This research examined the moderator association of digital culture 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 now also used as a moderator 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.

4.2 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 digital culture. 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.

4.3 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.

5. Conclusions

This research examines how artificial intelligence adoption impacts sustainable supply chain performance. It also aimed to determine the implications of moderator roles of digital culture in manufacturing organizations. Our research supports the proposed hypothesis that artificial intelligence has a positive impact on sustainable supply chain performance. Furthermore, digital culture has moderated 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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