

## IMPACT ARTIFICIAL INTELLIGENCE ON SUSTAINABLE PERFORMANCE IN SMES OF PAKISTAN. THE MEDIATING ROLE OF ALGORITHMIC TRUST

**Fahad Saddique\***

Ph.D. Scholar, Institute of Management Science, Lahore, Pakistan

Email: [Fahad.sadique@gmail.com](mailto:Fahad.sadique@gmail.com)

**Khalil Nasir Khan\*\***

Ph.D Scholar, Lincoln University College, Malaysia.

Email: [Khalilnasir9161@gmail.com](mailto:Khalilnasir9161@gmail.com)

**Sher Zaman\*\*\***

PhD Scholar Business Administration Gomal University DI Khan KPK, Pakistan

Email: [Sherzamanfuu@gmail.com](mailto:Sherzamanfuu@gmail.com)

### **Abstract:**

*According to the resource-based view, the study examines the adoption of artificial intelligence to enhance sustainable supply chain performance in SME' in Pakistan. More specifically, this study also determines the mediating role of algorithmic trust. The study is based on a quantitative, closed-ended questionnaire. This questionnaire is based on a sample of 290 from SMEs in Lahore, Pakistan. The study analysis was conducted using SPSS software. The study's findings suggest that adopting artificial intelligence has a significant positive impact on sustainable supply chain performance in SME firms. Furthermore, Algorithmic Trust 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.*

**Keywords:** The Adoption of Artificial Intelligence, Sustainable Supply Chain Performance Algorithmic Trust, and Small Medium Enterprises in Pakistan.

### **Introduction:**

Production in small and medium enterprises (SMEs) before the advent of the industrial revolution was conducted using a mass-production method that would be equally effective today (Dalenogare et al., 2018). Consumer preferences have evolved significantly since then; consumers want customized products and therefore require each stage of the production process to be adapted to satisfy their individualized requirements. Therefore, consumer expectations, along with the demand for standardized products, have led to more sophisticated, demanding supply chains. Additionally, technological advancements such as artificial intelligence (AI) offer companies greater opportunities to operate globally and make production easier (Brodner, 2015). Use of AI in workplaces is rapidly growing both in SMEs and foreign company settings (Hofmann & Rusch, 2017). Both the application of AI to drive economic development in developing nations and the "Hannover Messe Industries Fair" held in 2011 to address the impacts of integrating Cyber-Physical Systems (CPSs) into business models demonstrate the potential for AI-type disruption in the industrial automation sector (Sriram & Vinodh, 2021). The primary objective of this research area is to gather information and collect real-time data throughout all stages of the production process to support decision-making for all stakeholders and minimize expenses. The digitization of manufacturing processes in SMEs through AI-based applications will help them compete in their respective markets (Contreras et al., 2024). A variety of emerging digital technologies can be utilized to support this digitization of manufacturing processes. These include but are not limited to Internet of Things (IoT), Industrial Internet of Everything (IoE), CPS, Radio Frequency

Identification (RFID), Enterprise Resource Planning (ERP), Cloud-Based Manufacturing, Business Data Analytics (BD), Autonomous Robots, Simulation, etc. (Safavi et al., 2024). The impact of AI in manufacturing processes in SMEs is beneficial. Productivity is anticipated to grow by 55 percent and profitability margin by 15 percent with the use of advanced technologies in manufacturing processes (Raj et al., 2020). Digitalization of manufacturing processes has also enhanced communication among the various manufacturing machines and employees, resulting in better operational processes and increased operational efficiency, with reduced downtime (Salman et al., 2024). Collaboration between humans and machines is taking place to meet specific customer needs in the increasingly complex, personalized digital environment of manufacturing (Rahman et al., 2025). Digitalization of manufacturing processes has enabled manufacturers to adopt faster, more efficient methods and procedures for producing finished goods and delivering them to end customers (Hernandez et al., 2020). Global manufacturing industry SMEs are currently utilizing digitalization and AI implementation differently than they did previously in their production systems. This technique is superior to previous production techniques. The current trend toward digitalization and the implementation of AI in production systems is making them greener and more environmentally sustainable, providing a competitive edge for the manufacturing industry (Gillani et al., 2020). Benefits from implementing AI are anticipated to continue through the modularization of production processes and by capitalizing on operating systems such as AI, IoT, ERP, and other software systems to enhance the supply chain and product lifecycle management (Galati & Bigliardi, 2019). The impact of digitizing operational activities through Artificial Intelligence (AI) in production is most evident during the development of new products. Additionally, the digitization of the production process and its use of AI allows for the computerization of modeling and the monitoring and management of the input materials required by the production process, as well as monitoring and managing the sale and distribution of the end-products inside an organization or across various departmental units, including healthcare, agriculture, construction, food and manufacturing (Stefanini & Vignali, 2024). From this point of view, both the digitization of the production process and the use of AI in this context present a modern vision of the circular economy; they contribute to sustainable economic growth, improve the productivity of investments made by humans in Small and Medium Enterprises (SME), and provide performance improvements (Rajput & Singh, 2019). Furthermore, digital technologies implemented and improved automated advanced scheduling of production processes and maintenance, resulting in a significant decrease in maintenance costs. Consequently, improved equipment performance led to a larger output of final products (Aljanabi & Ghafour, 2021). Digitalization has had numerous impacts beyond those discussed above in manufacturing. These impacts have enabled both improvements and increased attention to operational activities at all stages. By implementing AI alongside sustainable business practices, AI has achieved these goals (Bag et al., 2023). Companies use AI to evaluate their long-term performance (Agyabeng-Mensah & Tang, 2021). More than ever before, AI and IoT are transforming the Supply Chain (SC) as we understand it today, providing greater productivity and efficiency for organizations (Meng et al., 2021). Eventually, platforms will be developed that serve as substitutes for traditional SCs (Zhou et al., 2022). About customer preferences, social media, mobile networks, and other electronic commerce-based digital platforms assist customers in making informed purchasing decisions. So far, the technology used to create these types of digital platforms has been applied to develop new digital systems that transform

traditional SCs, enabling users to see more information, work together more efficiently, and respond faster (Geodis, 2022). Technologies related to transparency are increasingly important tools for sharing information with individuals, enabling greater supply chain integration (Raymond et al., 2016).

## **2. Literature Review and Hypotheses**

### **2.1. Adoption Of Artificial Intelligence and Sustainable Supply Chain Performance:**

The Resource-based view can be an excellent method for a manager to evaluate their company's fit in the strategic management process. For years, managers have used RBT as a resource-based identification tool to identify resources that will give a company "a sustainable competitive advantage." Additionally, RBT serves as an extremely practical guide for companies to analyze and forecast their underlying source of competitive advantage (Utami & Alamanos, 2023). All organizations require an effective, enduring mechanism for maintaining continued success over time. Thus, organizations that employ artificial intelligence can produce more items more cheaply and deliver better services (Dash et al., 2019). While there have been numerous studies on the use of artificial intelligence and its impact on SCM in Saudi organizations, AI offers several additional benefits, including higher quality, increased efficiency, greater flexibility, and greater productivity (Alsharidah & Alazzawi, 2020). Over the past few years, there has been significant growth in researcher/practitioner interest in AI-based tools. The use of AI-based tools is essential for organizations to collaborate and resolve global environmental issues (Benzidia et al., 2021). The incorporation of AI into the food industry offers many benefits for consumers and communities while increasing public awareness of transparency, explainability, usability, and accountability (Manning et al., 2022). These technologies can increase the responsiveness and efficiency of business practices. Also, leveraging data diversity to enhance sustainable supply chain performance can reduce processing times, improve flexibility, and increase productivity (Dubey et al., 2022). AI has multiple functional uses to support customers, suppliers, and internal organizational functions, which support long-term performance (De Vass et al., 2018). AI enables improvements in the effectiveness of the value supply chain system (Rejeb et al., 2019). Also, the use of AI can improve data transfer/interaction/monitoring, resulting in improved compatibility and long-term performance (Gnimpieba et al., 2015). Another study found that AI increases trust and safety, reduces costs, increases efficiency, reduces waste, and changes views of sustainable performance (Queiroz et al., 2020). Additionally, AI implementation is key to obtaining sustainability (Maheshwari et al., 2021). The positive results of AI on sustainable supply chain performance are well documented (Bag et al., 2020). Also, AI can enable organizations to create supply chain reporting and ultimately improve long-term performance (Nicoletti & Appolloni, 2024). This study advocates for and outlines the benefits of using AI for collaborative supply chains, managing environmental uncertainty, and improving logistics resiliency and sustainable performance (Wang & Pan, 2022). AI has had a positive effect on the global supply chain system and has enabled organizations to achieve enhanced financial and operational results in terms of sustainable performance (Dubey et al., 2022). This study stated that AI has a significant impact on aspects of the SC process, including information flow and integration, and enables organizations to respond to potential risks more effectively (Nayal et al., 2022). AI-based solutions deliver accuracy, speed, and consistency in product delivery, enabling sustained performance (Goodarzian et al., 2023). AI, along with other cutting-edge technologies, is enabling supply chain activities to become more flexible, efficient, and

transparent. However, there are risks associated with disruptions to logistical networks, volatility in demand, and sustainability concerns (Chen et al., 2022). Therefore, using sustainable AI technology will positively affect performance (Yadav et al., 2021).

H1: The Adoption of Artificial Intelligence has positive relation with sustainable supply chain performance.

## **2.2 Mediating Role of Algorithmic Trust:**

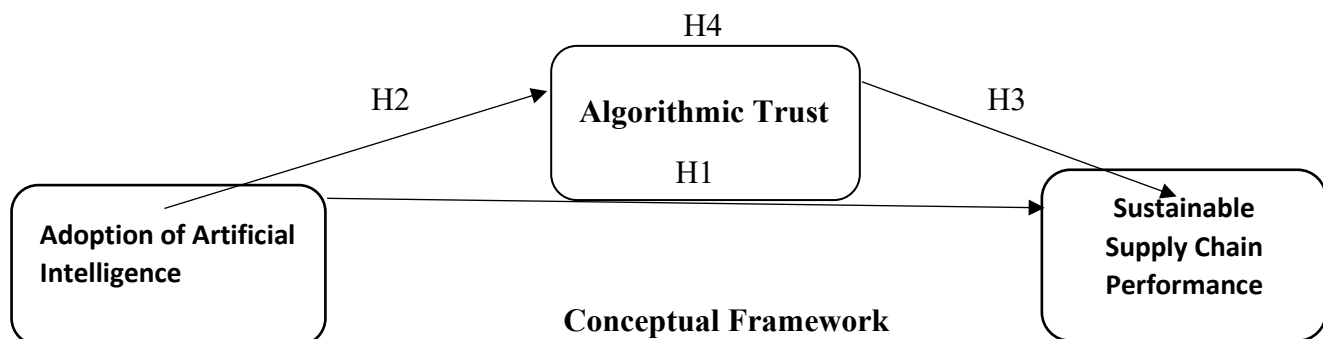
The development of technology is one of the major drivers of achieving sustainable performance in companies. This is especially true for smaller-sized businesses. For these types of companies, efficiency, innovation, and resource management are key to both survival and business growth. AI enables companies to process large amounts of data, improve decision-making accuracy, and enable greater operational efficiency. This results in improved environmental, social, and economic sustainability (Dubey et al., 2022). Although the use of AI will certainly increase a company's ability to make more accurate decisions, this alone does not guarantee success. The effectiveness of adopting new AI technologies also greatly depends on how much a user trusts and relies on the output generated by an AI system in the organization's decision-making process. Therefore, we have introduced the concept of Algorithmic Trust, which is defined as the willingness of individuals to rely on outputs produced by an AI system based on perceived reliability, transparency, and competency. Based upon Trust Theory, trust reduces uncertainty and enables individuals to rely on technological systems (Dubey et al., 2022). Since many AI systems produce outputs that are difficult for humans to understand due to opaque decision-making processes, algorithmic trust is a key factor in the acceptance and successful implementation of AI in organizational environments. Studies related to prior research indicate that AI systems that can analyze large amounts of data and provide accurate, reliable, and consistent information will significantly increase confidence in their output, thereby promoting trust (Glikson & Woolley, 2020). Previous research has demonstrated that people tend to believe AI systems can perform analytical and computational tasks competently, thereby enhancing cognitive trust and supporting AI adoption in organizational settings. Additionally, algorithmic trust serves as a critical psychological mediator connecting AI adoption to sustainable performance outcomes. Even though AI provides the technical basis for organizations to achieve sustainability improvements, these improvements cannot be realized if managers do not trust or effectively utilize AI-generated insights. If sufficient levels of trust do not exist, employees may reject suggestions made by AI, fail to fully utilize the capabilities offered by technology, or continue using traditional decision-making techniques, all of which would limit the full potential of AI to promote sustainability. On the other hand, when algorithmic trust is high within an organization, employees will be more inclined to incorporate AI-generated insights into their organizational decisions regarding strategy and operations. These activities will lead to higher resource utilization efficiency, reduced waste generation, improved coordination among supply chains, and ultimately improved overall sustainability performance. Furthermore, the existing literature supports the view that trust in AI is a multidimensional phenomenon involving perceptions of reliability, predictability, and fairness, each influencing behavioral reliance on AI systems (Bach et al., 2022; Lukyanenko et al., 2022). Most recently published research identified that trust in AI remains an emerging area of study with fragmented conceptual frameworks representing current knowledge of its role in organizational outcomes. Consequently, there appears to be a significant research gap in understanding the role of trust

in AI and its impact on organizational outcomes. Specifically, this research gap is even more pronounced for Small and Medium Enterprises (SMEs) operating in developing/emerging countries like Pakistan. There is an ongoing increase in technology adoption among SMEs operating in these countries; however, institutional support for technology adoption, digital literacy, and trust in advanced technologies remains underdeveloped relative to those in developed countries.

H2: There are positive relationship of AI on AT.

H3: There are positive relation of AT on SSCP.

H4: There are partial mediating role of AT in between AI and SSCP.



**3.1. Methodology:** The purpose of this study is to assess the impact of adopting Artificial Intelligence on Sustainable Supply Chain Performance of SMEs located in Lahore, Pakistan. In addition to having an intermediary function in relation to Algorithmic Trust. The methodologies/techniques used for the study were based on previous research on multidisciplinary studies (F, Saddique, Khalil, & N, Mushtaq et al., 2020-2026). Questionnaires were distributed to employees working at firms throughout Lahore. Of the 400 initially shared, 290 were returned.

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

| Variable                             | Items | Reference                |
|--------------------------------------|-------|--------------------------|
| Artificial Intelligence              | 3     | Chatterjee et al. (2023) |
| Algorithmic Trust                    | 4     | (Logg et al., 2019).     |
| Sustainable Supply Chain Performance | 5     | Ma et al. (2022).        |

Table: 3.2. Sample Distribution:

|        | Characters | F   | %    |
|--------|------------|-----|------|
| Gender | Male       | 219 | 75.5 |
|        | Female     | 71  | 24.5 |
|        | Total      | 290 | 100  |

|               |                    |     |       |
|---------------|--------------------|-----|-------|
| Ages          | Below than 25      | 51  | 17.5  |
|               | 26-40              | 121 | 41.7  |
|               | 41-55              | 80  | 27.5  |
|               | Above 55           | 38  | 13.1  |
| Qualification | Matric             | 30  | 10.3  |
|               | Intermediate       | 85  | 29.3  |
|               | Graduation         | 118 | 40.6  |
|               | Post Graduate      | 57  | 19.6  |
| Experience    | Less One Year      | 60  | 20.6  |
|               | From 1 to 5 years  | 70  | 24.1  |
|               | From 6 to 10 Years | 120 | 41.3  |
|               | Above 10 years     | 40  | 13.79 |

Explanation: The gender split of the survey population is given in Table 3.2. A total of 219 people, or 75.5% of all participants, were males, while 71, or 24.5% of all participants, were females. The age group distribution of the participants is also broken down into five different categories. As shown in the table, most participants fall within the age range of 26 to 40, totaling 121 participants (41.7%). Also, 38 participants are 55 years or older, which makes up 13.1% of all participants. Participants' qualifications were divided into four categories. Most participants are graduate-level students from the University at a rate of 118 (or 40.6%), and a few participants had matric education at a rate of 30 (or 10.3%). Lastly, based on their work experience, the participants were further divided into four categories. 120 participants had 6 to 10 years of experience, at a rate of 41.3%, and 40 participants had more than 10 years of experience, at a rate of 13.79%.

Table#, 3.3: Reliability Analysis:

| Variable                             | No of Items | Cronbach's Alpha |
|--------------------------------------|-------------|------------------|
| Artificial Intelligence              | 3           | 0.89             |
| Algorithmic Trust                    | 4           | 0.92             |
| Sustainable Supply Chain Performance | 5           | 0.94             |

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.

### 3.4. Correlation Analysis:

**Correlation Analysis Table:**

| Variables                  | 1       | 2 |
|----------------------------|---------|---|
| 1. Artificial Intelligence | 1       |   |
| 2. Algorithmic Trust       | 0.378** | 1 |

3. Sustainable SC Performance                      0.342\*\*                      0.512\*\*

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

Explanation: Table 3.4 shows how these variables are interrelated. There was a significant positive correlation of moderate strength ( $r = .378$ ,  $p = .00$ ) between artificial intelligence and algorithmic trust. Also, there was a significant positive correlation of moderate strength ( $r = .3432$ ,  $p = .000$ ) between artificial intelligence and sustainable supply chain performance. Finally, the relationship between algorithmic trust and sustainable supply chain performance was very strong and statistically significant ( $r = .512$ ,  $p = .000$ ).

### 3.5. Regression Analysis

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

| Variable                | R <sup>2</sup> | B     | t    | sig   |
|-------------------------|----------------|-------|------|-------|
| Artificial intelligence | 0.119          | 0.248 | 7.89 | 0.000 |

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

Explanation: Table 3.5.1 illustrates the initial regression analysis used to evaluate the relationship between artificial intelligence and sustainable supply chain performance. Since the ANOVA F statistic is significant ( $\text{sig} = 0.00$ ), the model fits well. An R-squared of 0.119 shows that each unit increase in artificial intelligence will result in an 11.9 percent improvement in sustainable supply chain performance. As such, the p-value for the coefficient ( $p = .00$ ), which is less than 0.05, provides evidence of a statistically significant relationship between artificial intelligence and sustainable supply chain performance. Therefore, as indicated by the positive B value (.248) representing artificial intelligence's effect on sustainable supply chain performance, Hypothesis 1 is accepted.

#### 3.5.2. Model between artificial intelligence and algorithmic trust.

| Variable                | R <sup>2</sup> | B     | t    | sig   |
|-------------------------|----------------|-------|------|-------|
| Artificial Intelligence | 0.189          | 0.423 | 8.23 | 0.000 |

Dependent variable: Algorithmic Trust, \* $p < 0.05$ .

Explanation: Regression table # 3.5.2. shows a simple regression analysis of how artificial intelligence influences trust in algorithms. Since the F-statistic (ANOVA)  $p\text{-value} = 0.00 < 0.05$ , we can conclude that the model fits well. Based on R-squared = 0.189, for each unit increase in AI, there will be a corresponding 18.9 percent change in Trust in Algorithms. The p-value of  $B = 0.00$ , which is below the 0.05 threshold, indicates a relationship between the two variables. Therefore, based on the above information, hypothesis 2 appears to be confirmed.

#### 3.5.3. Model between algorithmic trust and sustainable supply chain performance

| Variable          | R <sup>2</sup> | B     | t      | sig   |
|-------------------|----------------|-------|--------|-------|
| Algorithmic trust | 0.289          | 0.523 | 11.218 | 0.000 |

Dependent Variable: Sustainable Performance, \* $p < 0.05$ .

Explanation: Beginning with the fact that Table 3.5.3 illustrates an initial regression analysis of how supply chain integration impacts sustainable supply chain performance. Since there is no reason to believe otherwise from the information provided (the ANOVA sig value = .00 < .05), the model can be said to fit. Therefore, if we take a unit increase in Algorithmic Trust, we would see a 28.9% increase in Sustainable Supply Chain Performance ( $R^2 = .289$ ). Furthermore, the p-value for the Coefficient (B), as previously mentioned, is less than .05 (.00); therefore, it can be concluded that there is a statistically significant relationship between these two variables. In addition, the B value for this equation is 0.523; thus, it is evident that Algorithmic Trust has a direct effect on sustainable supply chain performance. As such, Hypothesis #3 is supported.

#### 3.5.4 Mediation Analysis:

Table 3.5.4: Mediation analysis using through Bootstrap

| Relationships     | $\beta$ | P   | Bootstraps |       | @ | Hypotheses |
|-------------------|---------|-----|------------|-------|---|------------|
|                   |         |     | 95%        |       |   |            |
|                   |         |     | LL         | UL    |   |            |
| <i>AI→AT→SSCP</i> |         |     |            |       |   |            |
| Direct effect     | 0.128   | *** | 0.110      | 0.218 |   |            |
| Indirect effect   | 0.432   | *** | 0.356      | 0.567 |   |            |

Note: AI=Artificial Intelligence, AT= Algorithmic Trust, SSCP= Sustainable Supply Chain Performance, \*\*\* $p < 0.01$

Explanation: The mediating variable hypothesis was evaluated using 1000 bootstrap samples, and 95% confidence intervals were established. The role of algorithmic trust as a mediator with artificial intelligence and sustainable supply chain performance: the indirect effect (0.432, LL = 0.356, UL = 0.567,  $P = 0.01$ ) was smaller than the direct effect ( $\beta = 0.128$ ,  $P = < 0.01$ ). There was no "0" value between upper and lower limits; therefore, Hypothesis H5 is accepted. Algorithmic trust partially mediates the association between artificial intelligence and sustainable supply chain performance.

**4.1. Discussion:** The RBT provides a particularly useful framework for assessing and projecting a company's strong competitive advantage (Utami & Alamanos, 2023) to sustain continued success over time. Organizations need a successful, long-lasting process to continue achieving their goals. Additionally, organizations using Artificial Intelligence can produce better products and services at lower prices than other companies (Dash et al., 2019). Although AI technology will have a significant impact on the SCM of Saudi businesses, it also offers many other advantages, including better-quality products, greater efficiency, greater flexibility, and higher productivity (Alsharidah & Alazzawi, 2020). There has been a lot of attention recently on researcher and practitioner tools that utilize AI. Businesses need to use AI tools to collaborate and solve global environmental issues (Benzidia et al., 2021). The utilization of AI in the "food industry" is advantageous to both customers and communities alike while increasing awareness of areas like openness, explanations, user-friendliness, and accountability

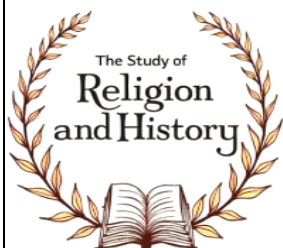
(Manning et al., 2022). These types of technologies can help businesses become even more responsive and efficient. Also, the ability to leverage data variety for sustainable SC performance enables business processes to occur faster, more flexibly, and more productively (Dubey et al., 2022). The use of AI can also support future performance in various ways by providing capabilities that aid customer-facing, supplier-facing, and internally focused organizational operations (De Vass et al., 2018). The use of AI can improve the functionality of the value supply chain system (Rejeb et al., 2019). Additionally, the use of AI can enhance the functionality of information exchange, communication, and monitoring,, allowing for better compatibility and long-term performance (Gnimpieba et al., 2015). Another study demonstrates that the use of AI increases trust and safety, decreases costs, operates efficiently, reduces waste, and modifies our perception of sustainable performance (Queiroz et al., 2020). Moreover, the implementation of AI is critical to achieving sustainability (Maheshwari et al., 2021). AI technologies allow organizations to handle vast amounts of data, enhance decision-making accuracy, and optimize operational efficiency, leading to sustainable environmental, social, and economic results (Dubey et al., 2022). However, the effectiveness of adopting AI is not solely dependent on an organization's technical capacity, but rather on whether users believe in and depend on AI systems when making decisions within the organization. This brings about the notion of algorithmic trust. According to Trust Theory, an individual's trust in technology depends on their belief in its reliability, transparency, and competence (Dubey et al., 2022). Based on this definition, trust plays a vital role in decreasing uncertainty and encouraging dependence on technological systems (Dubey et al., 2022). All discussions concluded that the Adoption of AI has a positive Impact on SSCP. Additionally, Algorithmic trust partially mediates AI and SSCP. Thus, all hypotheses were confirmed (H1-H4).

**5. Conclusions:** This research investigates how the adoption of artificial intelligence (AI) affects sustainable supply chain performance. In addition, this research was designed to investigate the potential implications of algorithmic trust as a mediator in SME firms. The findings from our research support the proposed hypothesis that AI will have a positive effect on sustainable supply chain performance. Additionally, we found that algorithmic trust partially mediates the relationship between artificial intelligence and sustainable supply chain performance. Ultimately, this research provides valuable information for business owners to invest in technology to achieve improved business results.

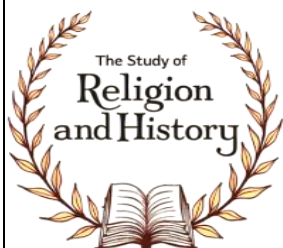
#### **6. Reference:**

1. Agyabeng-Mensah, Y., & Tang, L. (2021). The relationship among green human capital, green logistics practices, green competitiveness, social performance and financial performance. *Journal of Manufacturing Technology Management*, 32(7), 1377-1398.
2. Algorithm appreciation: People prefer algorithmic to human judgment. *Organization Behavior and Human Decision Processes*, 151, 90–103
3. Aljanabi, A. R. A., & Ghafour, K. M. (2021). Supply chain management and market responsiveness: a simulation study. *Journal of Business & Industrial Marketing*, 36(1), 150-163.
4. Alsharidah, Y. M. Y., & Alazzawi, A. (2020, October). Artificial intelligence and digital transformation in supply chain management a case study in Saudi companies. In *2020 international conference on data analytics for business and industry: way towards a sustainable economy (ICDABI)* (pp. 1-6). IEEE.

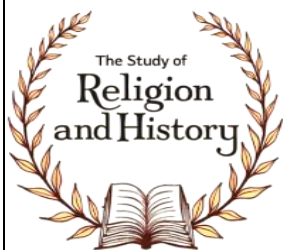
5. Anjum, R., Daud, S., Bhatti, G. A., & Saddique, F. (2026). Evaluation of AI-based mental health interventions using the grey relational analysis. *Grey Systems: Theory and Application*, 16(1), 75-90.
6. Bach, T. A., et al. (2022). User trust in AI-enabled systems: A systematic review. *International Journal of Human-Computer Interaction*.
7. Bag, S., Rahman, M. S., Srivastava, G., Shore, A., & Ram, P. (2023). Examining the role of virtue ethics and big data in enhancing viable, sustainable, and digital supply chain performance. *Technological Forecasting and Social Change*, 186, 122154. DOI: <https://doi.org/10.1016/j.techfore.2022.122154>
8. Benzidia, S., Makaoui, N., & Bentahar, O. (2021). The impact of big data analytics and artificial intelligence on green supply chain process integration and hospital environmental performance. *Technological forecasting and social change*, 165, 120557.
9. Brodner, K. (2015). Digital Enterprise-Fertigungs-und Prozessindustrie auf dem Weg zu Industrie 4.0. *Handelsblatt Journal-Sonderveröffentlichung zum Thema „Industrie*, 4, 12.
10. Contreras, F., Jauregui, K., & Rank, S. (2024). The intellectual structure of human resource management and digitalization research: A bibliometric-mapping analysis. *Journal of Engineering and Technology Management*, 73, 101829.
11. Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of production economics*, 204, 383-394.
12. Dash, R., McMurtrey, M., Rebman, C., & Kar, U. K. (2019). Application of artificial intelligence in automation of supply chain management. *Journal of Strategic Innovation and Sustainability*, 14(3).
13. De Vass, T., Shee, H., & Miah, S. J. (2018). The effect of “Internet of Things” on supply chain integration and performance: An organisational capability perspective. *Australasian Journal of Information Systems*, 22.
14. Dubey, R., Bryde, D. J., Dwivedi, Y. K., Graham, G., & Foropon, C. (2022). Impact of artificial intelligence-driven big data analytics culture on agility and resilience in humanitarian supply chain: A practice-based view. *International Journal of Production Economics*, 250, 108618. DOI:
15. Galati, F., & Bigliardi, B. (2019). Industry 4.0: Emerging themes and future research avenues using a text mining approach. *Computers in industry*, 109, 100-113.
16. GEODIS Khan, M., Parvaiz, G. S., Dedahanov, A. T., Abdurazzakov, O. S., & Rakhmonov, D. A. (2022). The impact of technologies of traceability and transparency in supply chains. *Sustainability*, 14(24), 16336.
17. Gillani, F., Chatha, K. A., Jajja, M. S. S., & Farooq, S. (2020). Implementation of digital manufacturing technologies: Antecedents and consequences. *International Journal of Production Economics*, 229, 107748.
18. Glikson, E., & Woolley, A. W. (2020). Human trust in artificial intelligence: Review of empirical research. *Academy of Management Annals*, 14(2), 627–660.
19. Gnimpieba, Z. D. R., Nait-Sidi-Moh, A., Durand, D., & Fortin, J. (2015). Using Internet of Things technologies for a collaborative supply chain: Application to tracking of pallets and containers. *Procedia Computer Science*, 56, 550-557.



20. Goodarzian, F., Navaei, A., Ehsani, B., Ghasemi, P., & Muñuzuri, J. (2023). Designing an integrated responsive-green-cold vaccine supply chain network using Internet-of-Things: artificial intelligence-based solutions. *Annals of Operations Research*, 328(1), 531-575.
21. Helmrich, K. (2015). Digital Enterprise-Fertigungs-und Prozessindustrie auf dem Weg zu Industrie 4.0. *Handelsblatt Journal-Sonderveröffentlichung zum Thema „Industrie*, 4, 12.
22. Hernandez-de-Menendez, M., Morales-Menendez, R., Escobar, C. A., & McGovern, M. (2020). Competencies for industry 4.0. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 14(4), 1511-1524.
23. Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in industry*, 89, 23-34.
24. Khan, K. N. (2025). PSYCHOLOGICAL CAPITAL TO INNOVATION FROM DIGITAL TECHNOLOGY TO CYBERLOAFING IN PAKISTANI UNIVERSITIES. *International Journal of Applied Mathematics*, 38(7s), 722-745.
25. Khan, K. N., Anjum, S., Abbas, M. M., & Jabeen, A. (2024). Unlocking Teacher's Innovative Work Performance with Idiosyncratic Deals. The Parallels Mediating Models of Pakistani Universities. *International Journal of Social Science Archives (IJSSA)*, 7(2).
26. Khan, K. N., Shah, M. H., & Saddique, F. (2025). Innovative Work Behaviour Amid Faculty Shortage: The Role of Idiosyncratic-Deals, Digital Technology and Perceived Leadership Support. *Journal of Posthumanism*, 5(4), 978-992.
27. Lukyanenko, R., Maass, W., & Storey, V. C. (2022). Trust in artificial intelligence: A foundational framework. *Electronic Markets*, 32, 1993–2020.
28. Maheshwari, S., Gautam, P., & Jaggi, C. K. (2021). Role of Big Data Analytics in supply chain management: current trends and future perspectives. *International Journal of Production Research*, 59(6), 1875-1900.
29. Manning, L., Brewer, S., Craigon, P. J., Frey, J., Gutierrez, A., Jacobs, N., ... & Pearson, S. (2022). Artificial intelligence and ethics within the food sector: Developing a common language for technology adoption across the supply chain. *Trends in Food Science & Technology*, 125, 33-42.
30. Maroof, L., Basit, A., & Khan, K. N. (2022). Responsiveness of Banks' Stability Towards Peak and Trough Phases of Business Cycle: A Comparative Analysis of Islamic Banks and Conventional Banks. *COMSATS Journal of Islamic Finance (CJIF)*, 7(2).
31. Meng, Q., Lai, X., Yan, Z., Su, C. Y., & Wu, M. (2021). Motion planning and adaptive neural tracking control of an uncertain two-link rigid-flexible manipulator with vibration amplitude constraint. *IEEE Transactions on Neural Networks and Learning Systems*, 33(8), 3814-3828.
32. Mushtaq, F. S. U. N. N., & Ali, B. L. A. (2023). Implementation of digitalization supply chain helps in gaining of competitive advantages as mediating role in the supply chain performance in construction organization in Pakistan. *Journal of Humanities*, 1(01), 14-27.
33. Mushtaq, N., & Khattak, A. N. (2026). Adoption of Solar Energy Sources and Sustainable Performance for Environment in Power Sector of Pakistan: An Empirical



- Analysis Based on Mediation Model of Green Innovation. *The Critical Review of Social Sciences Studies*, 4(1), 1690-1701.
34. Mushtaq, N., & Khattak, A. N. (2026). Deployment of Wind Powered Resources and Ecologically Sound Performance in Pakistan's Energy Sector: An Empirical Research Based on the use of Green Technology Mediation Model. *Journal for Social Science Archives*, 4(1), 466–479. <https://doi.org/10.59075/jssa.v4i1.501>
  35. Mushtaq, N., Badar, M., Akhtar, F., Batool, F., Sandhu, M. E., Khan, M. I., ... & Zia, M. A. (2021). Efficiency of Power Distribution Companies in Pakistan (Application of Non-Parametric Approach).
  36. Mushtaq, N., Mirza, H. H., Rehman, S. U., & Saddique, F. (2020). Efficiency of Power Generation Companies in Pakistan: Application of Non-Parametric Approach. *Ilkogretim Online*, 19(4), 3486-3504.
  37. Mushtaq, N., Saddique, F., Abbas, Z., & Nawaz, M. (2023). How important is Efficiency in any Organization?“Estimating the Efficiency Reform of Power Distribution Companies in Punjab Province, Pakistan”(LESCO, FESCO & IESCO). *Traditional Journal of Law and Social Sciences*, 2(01), 44-59.
  38. Nawaz, M., Khan, S. A., Rana, S. L., & Saddique, F. (2020). Role Of Human Resource Best Practices To Improve Quality Education Of Pakistani Schools. *International Journal of Management (IJM)*, 11(11).
  39. Nayal, K., Raut, R., Priyadarshinee, P., Narkhede, B. E., Kazancoglu, Y., & Narwane, V. (2022). Exploring the role of artificial intelligence in managing agricultural supply chain risk to counter the impacts of the COVID-19 pandemic. *The International Journal of Logistics Management*, 33(3), 744-772.
  40. Naz, F., Manzoor, A., Khan, K. N., & Ali, L. (2021). Islamic Equities Volatility and US Economic Influence: Case of Emerging Market. *COMSATS Journal of Islamic Finance (CJIF)*, 6(2).
  41. Nicoletti, B., & Appolloni, A. (2024). A framework for digital twins solutions for 5 PL operators. *Technology in Society*, 76, 102415.
  42. Nwagwu, U., Niaz, M., Chukwu, M. U., & Saddique, F. (2023). The influence of artificial intelligence to enhancing supply chain performance under the mediating significance of supply chain collaboration in manufacturing and logistics organizations in Pakistan. *Traditional Journal of Multidisciplinary Sciences*, 1(02), 29-40.
  43. Queiroz, M. M., Telles, R., & Bonilla, S. H. (2020). Blockchain and supply chain management integration: a systematic review of the literature. *Supply chain management: An international journal*, 25(2), 241-254.
  44. Rahman, M., Emon, M. E. H., Antor, M. H., Haque, S. A., & Talapatra, S. (2025). Identification and prioritization of barriers to Industry 4.0 adoption in the context of food and beverage industries of Bangladesh. *Benchmarking: An International Journal*, 32(2), 757-783.
  45. Rajput, S., & Singh, S. P. (2019). Identifying Industry 4.0 IoT enablers by integrated PCA-ISM-DEMATEL approach. *Management decision*, 57(8), 1784-1817.
  46. Raymond, N. A., Card, B., & al Achkar, Z. (2015, October). What is 'Humanitarian communication'? Towards standard definitions and protections for the humanitarian use of ICTs. In *European Interagency Security Forum (EISF)*.



47. Rejeb, A., Keogh, J. G., & Treiblmaier, H. (2019). Leveraging the internet of things and blockchain technology in supply chain management. *Future Internet*, 11(7), 161. DOI:
48. Saddique, F., & Khan, M. I. (2026). Impact of Adoption of Artificial Intelligence in Sustainable Supply Chain Performance in Manufacturing Organization of Pakistan: The Mediating Role of Supply Chain Integration. *The Critical Review of Social Sciences Studies*, 4(1), 1763-1776.
49. Saddique, F., Khan, K. N., Joyia, S. Z., & Jabeen, A. (2024). IMPACT OF INTERNET OF THINGS ON SUSTAINABLE SUPPLY CHAIN PERFORMANCE: THE EMPIRICAL PARALLEL MEDIATION MODELS. *PAKISTAN ISLAMICUS (An International Journal of Islamic & Social Sciences)*, 4(02), 76-89.
50. Saddique, F., Mushtaq, N., Hasan, R., Rehman, Z. U., & Ali, M. (2022). Access and Secure Storage Based Block Chain Scheme with IPFS Implemented in Electronic Medical Record in Lahore, Pakistan. . *Netw. Commun. Syst. JNACS*, 5(4).
51. Saddique, F., Mushtaq, N., Imran, Z., Nawaz, M., & Usman, M. (2021). Impact of Green Supply Chain Management Practices on Environment Performance and Competitive Advantage.
52. Saddique, F., Patel, K. R., Niaz, M., Chukwu, M. U., & Nwagwu, U. (2023). Impact of supply chain transformation on supply chain performance: the empirical study that bases on mediating role of supply chain resilience on construction organization on Pakistan. *Asian Journal of Engineering, Social and Health*, 2(9), 1072-1086.
53. Saddique, F., Ramzan, B., Sanyal, S., & Alamari, J. (2023). Role of digital leadership towards sustainable business performance: A parallel mediation model. *Journal of Infrastructure, Policy and Development*, 7(3), 2416.
54. Safavi Jahromi, G., & Ghazinoory, S. (2025). Clothing industry in transition from Industry 4.0 to Industry 5.0. *The Journal of The Textile Institute*, 116(3), 365-379.
55. Salman, S., Hasanat, S., Rahman, R., & Moon, M. (2024). Analyzing the key barriers of adopting Industry 4.0 in Bangladesh's ready-made garment industry: an emerging economy example. *International Journal of Industrial Engineering and Operations Management*, 6(3), 232-255.
56. Scholar, F. S. P. D., Fatima, H., Hassan, M., Scholar, N. M. P. D., & Asghar, K. A. (2023). Impact of ethical leadership on creative work performance: the empirical mediating roles of work engagement and attitude toward performing wells in construction organizations in Pakistan.
57. Shah, M. H. (2025). Strengthening Innovative Work Behavior via Psychological Capital: A Moderated Mediation Framework. *FishTaxa-Journal of Fish Taxonomy*, 36(1s), 90-101.
58. Sharif, S., Lodhi, R. N., Iqbal, K., & Saddique, F. (2022). Gender disparity in leadership boosts affective commitment and tacit knowledge sharing about libraries. *International Journal of Organizational Analysis*, 30(5), 1212-1234.
59. Sharif, S., Lodhi, R. N., Siddique, F., & Munir, M. A. (2021). Service quality of higher education digital library (DL) and loyalty behaviors: Testing the mediating role of student satisfaction. *Library Philosophy and Practice*, 1-22.
60. Shinta, D., Khan, K. N., & Nadeem, M. (2025). Evaluating Generative AI Initiatives in Human Resources: Multiple Criteria Decision Analysis. *Management Science and Business Decisions*, 5(2), 5-19.

61. Sriram, R. M., & Vinodh, S. (2021). Analysis of readiness factors for Industry 4.0 implementation in SMEs using COPRAS. *International Journal of Quality & Reliability Management*, 38(5), 1178-1192.
62. Stefanini, R., & Vignali, G. (2024). The influence of Industry 4.0 enabling technologies on social, economic and environmental sustainability of the food sector. *International Journal of Production Research*, 62(10), 3800-3817.
63. Unlocking Innovativeness through the Idiosyncratic Deals of University Teachers in Pakistan. The Empirical Mediating Role of Attitude Toward Performing Wells. (2024). *INTERNATIONAL JOURNAL OF HUMAN AND SOCIETY*, 4(1), 1227-1236. <https://ijhs.com.pk/index.php/IJHS/article/view/506>
64. Utami, H., & Alamanos, E. (2023). Resource-based theory: A review. *TheoryHub Book*. <https://open.ncl.ac.uk>.
65. Wang, M., & Pan, X. (2022). Drivers of artificial intelligence and their effects on supply chain resilience and performance: an empirical analysis on an emerging market. *Sustainability*, 14(24), 16836.
66. Zhou, L., Jin, F., Wu, B., Wang, X., Lynette Wang, V., & Chen, Z. (2022). Understanding the role of influencers on live streaming platforms: when tipping makes the difference. *European Journal of Marketing*, 56(10), 2677-2697.