



Smart Technologies Adoption and Sustainable Performance: The Intervening Role of Sustainable Supply Chain Management

Shahzad Akram¹, Dr. Mubashar Ali²

¹ PhD Scholar, Faculty of Business and Management Sciences, The Superior University, Lahore, Punjab, Pakistan.

Email: PHBA-F21-017@superior.edu.pk

² Associate Professor, Chaudhry Abdul Rahman Business School (CARBS), The Superior University, Lahore, Punjab, Pakistan.

Email: pmec@superior.edu.pk

ARTICLE INFO	ABSTRACT
Submission: August 23, 2026 Revised: September 04, 2026 Accepted: September 21, 2026 Available Online: October 01, 2026 Keywords: Smart Technologies, Artificial Intelligence, Internet of Things, Block Chain, Sustainable Supply Chain Management, Sustainable Performance Corresponding author: Dr. Mubashar Ali Email: pmec@superior.edu.pk	The rapid development of smart technologies and adoption make the world-wide market more competitive. Due to which sustainable performance has become a strategic tool and requirement to remain competitive in the market especially for the developing countries. The adoption of industry 4.0 technologies mainly Artificial Intelligence (AI), Internet of Things (IoT) and Blockchain Technology (BCT) is becoming crucial to remain competitive in the rapidly growing market. The main objective of this paper is to examine the impact of these technologies on sustainable performance in addition the mediating effect of sustainable supply chain management (SSCM) on these relationships. To achieve the purpose of this research, a theoretical and conceptual model has been developed. The data used in this research were collected from garment industries located in Punjab Pakistan through questionnaire with convenience sampling technique. The 847 responses in total were received. The SMARTPLS was applied on collected data to analyse the results. The results revealed that all hypotheses were accepted unless the one hypothesis which was not accepted in direct relation but accepted through mediation. This indicate that majority of the hypotheses were positive and statistically significant especially the internet of thing and block chain shows positive impact towards sustainable performance whereas artificial intelligence remains insignificant yet positive. Meanwhile, all three technologies exhibit significant results towards indirect effect of sustainable supply chain management. This study is the first to explore these hypothesized relationships collectively, it was able to develop new perspectives regarding Industry 4.0 technologies and their possible effects on supply chain and sustainable performance. Additionally, the research provides a empirical evidence from a developing country context.

Introduction

In this digital age three key technologies emerged; blockchain technology (BCT), artificial intelligence (AI), and the Internet of Things (IoT) and together, these technologies enhanced operational efficiency and helps in achieving sustainability goals. They also revolutionized corporate operations, optimized resources, and propelled sectors toward sustainability. Through enhanced automation, data-driven decision-making, and decentralized systems, these technologies form the cornerstone of the Fourth Industrial Revolution and impact the nature of employment in the future. As part of the "Industry 4.0" revolution, cutting-edge technologies like block chain technology, artificial intelligence, and the Internet of Things are being incorporated into production processes.

The garment sector has to be acknowledged as the strategic sector for Pakistan, so the policymakers have to come forward to fund the development of a strong digital platform and human resources. As Pakistan garment sector plays a significant role towards economic development especially, Punjab region garment sector is a major contributor to employment and exports. However, this

sector face different challenges in context of developing country like resource inefficiency, difficulty in compliance with international sustainability standards. To remain competitive in global market there is a need to adopt technologies to upgrade sustainability across supply chain operations.

In Pakistan, a favorable policy culture can ease the following challenges associated with the implementation of technology: financial problems, infrastructure problems, and cultural problems (Tornatzky and Fleischer, 1990). Meaningful fiscal and financial incentives, such as tax credits, subsidies, and grants, help in persuading the firms to become innovative. For instance, funding to buy IoT devices, AI software, or blockchain systems shall reduce the cost barriers to the uptake of the technologies (Rehman et al., 2022). Lack of supportive government policies leads to discouraging more investment in new technologies and has also been a major setback to the sector's competence to compete in the global market. A perfect policy mix for IT adoption should aim at offering incentives to promote technology use, and align policies with global sustainable development goals (Tornatzky & Fleischer, 1990).

Table 1: Research Gap

Author (Year)	Research done	Gap in their Research
Bag, S., Gupta, S., Pretorius (2021)	Investigated how technology contributes to the circular economy, with an eye towards environmentally responsible manufacturing and consumption.	In developing nations like Pakistan, there has been less emphasis on implementing Industry 4.0 technologies.
Bates, T., Khan, Z., Zhu (2021)	Read information on SSCM and its uses in different sectors.	For some industries, like textiles, there is a dearth of data showing how Industry 4.0 solutions improve SSCM.
Carter, C.R., Rogers (2008)	Sustainable supply chain management was proposed with an emphasis on social and environmental aspects.	Advanced technologies such as AI, IoT, and blockchain cannot be integrated into the framework at this time.
Dahlstrom, P., Ewing, M., Rasmussen (2015)	The researcher spoke about the supply chain digital transformation operating model of the future.	Problems unique to underdeveloped nations' attempts to execute digital transformation are left out of the study.
Govindan, K., Soleimani, H., Kannan (2020)	An integrated strategy was suggested for measuring supply chain sustainability performance.	Industry 4.0 technologies and their potential impact on sustainability objectives are left out of the research.
Iqbal, M.W., Hu, H., Zhu (2019)	Examined how sustainable performance in the construction industry is impacted by green procurement techniques.	The RMG sector is not covered by the study, which focuses solely on the building industry.
Jabbour, C.J.C., et al. (2020)	Analysed how mutually beneficial Industry 4.0 technologies are for environmentally responsible supply chains.	There has been little discussion of the difficulties emerging nations face when trying to implement Industry 4.0.
Kamble, S.S., Gunasekaran, A., Dhone (2018)	A sustainable supply chain and Industry 4.0 were suggested as a framework.	Certain industries, like textiles, have not provided empirical confirmation for the concept.
Lee, S.M., Lim, S. (2020)	Had a conversation on supply chain management and blockchain technology, with an emphasis on how the two can work together.	Concerns about blockchain's applicability in underdeveloped nations are ignored in the research.
Pereira, A.C., Romero, F. (2017)	The researcher looked at what Industry 4.0 means and how it will affect production.	Sustainability in the supply chain as it relates to Industry 4.0 has received little attention.
Seuring, S., Müller, M. (2008)	Built a model for environmentally responsible supply chain operations.	The Internet of Things (IoT), blockchain, and artificial intelligence (AI) integration are missing from the framework.

Zhu, Q., Sarkis, J., Lai (2012)	Examined the benefits of green supply chain management methods on performance improvements.	There has been little investigation into how digital tools could improve environmentally friendly supply chain procedures.
--	---	--

Based on the research gap given in table 1, existing literature gives mixed results towards emerging technologies and sustainable performance. Some revealed that technologies significantly enhance performance and some paid less attention to other technologies like internet of things and block chain technology. In the prior research, each technology is tested solely and combine effect of all technologies on performance is limited. Moreover, the existing literature gives the evidence conducted mostly in developed countries where organization technological infrastructure is strong. In the context of developing countries like Pakistan, the empirical evidence on the adoption of these technologies and their impact on sustainable performance is limited. For this purpose, this research addresses those gaps by examining the direct impact of Artificial intelligence, Internet of Things and Block Chain Technology on sustainable performance in garment sector of Punjab Pakistan. The research provides a more detailed and comprehensive understanding of how the integration of multiple technologies contributes to sustainability of organization.

The following research questions was examined in this research:

1. How does Artificial Intelligence affect sustainable performance in readymade garment sector of Punjab Pakistan?
2. How does Internet of Things affect sustainable performance in readymade garment sector of Punjab Pakistan?
3. How does Block Chain Technology affect sustainable performance in readymade garment sector of Punjab Pakistan?
4. Is there any positive relationship between emerging technologies, sustainable supply chain management and Sustainable Performance?

Literature Review

AI is the development of computer systems that perform human-like tasks, including learning from data, recognizing patterns, making decisions, and solving problems. AI technologies involve techniques aimed at creating systems that can simulate human cognitive functions, such as machine learning, natural language processing, computer vision, and robotics. (Russell & Norvig, 2021). During this period on competition, AI implementation has now become one of the major components to the success of the firm. Pakistan's garment industry can integrate AI-driven cutting and optimization systems to achieve sustainability and production cost reductions, as well as textile waste reductions that mirror international sustainability patterns.

Businesses use AI technology to improve their workforce's operational excellence and handle employee labour needs. Manufacturing operations in Pakistan's garment industry depend heavily on workforce availability because much factory work currently exists through manual means. AI-workforce management tools combine worker data about performance measurements alongside efficiency metrics and live production data to schedule workers efficiently (Boschma, 2007). AI-powered smart scheduling systems match jobs to workers through their expertise and accumulated work experience while also considering live manufacturing requirements according to Jamil et al. (2020). The system distributes workloads uniformly throughout all production teams so they maintain optimal productivity. Platform-based training modules supported by AI smart assistants deliver automated instructional programs and electronic educational resources that advance garment workers' technical expertise (Breschi, 2001).

When performance tracking systems with AI were used in Bangladesh's clothing industry, workers became 25% more productive, which cut down on mistakes and production delays (Breschi, 2009). AI-led labour management solutions, when adopted for Pakistan's textile sector, will enhance workforce performance, staff retention rates, and manufacturing efficiency throughout factories. When clothing factories use AI predictive maintenance systems, operational efficiency goes up because of predictive diagnostics, and equipment problems happen less often (Chaminade, 2011). Current maintenance practices in textile manufacturing follow pre-planned protocols and reactive maintenance upon equipment failure, causing unpredictable production stoppages and expensive repairs (Eder, 2018).

The Internet of Things refers to a network of interrelated physical devices, vehicles, home appliances, and other items that are embedded with sensors, actuators, software, and connectivity, and, for that reason, the items can collect, exchange, and analyze data. Devices can communicate with each other through this interconnectivity, enabling remote monitoring, control, and optimization. (Atzori et al., 2010). IoT sensors make AI machine monitoring systems possible. These systems use real-time data

analytics to find worn-out equipment before it breaks down (Edquist, 2019). The predictive analytics capabilities of AI systems determine machine failure times along with service needs, which allow factories to schedule preventive maintenance before equipment fails (Eghbal, 2017). Leading global textile manufacturers implemented predictive maintenance solutions driven by artificial intelligence technology to reduce their equipment downtime by more than 40% while extending the lifespan of their textile equipment (Gertler, 2005). Many Pakistani garment industries using outdated machinery would benefit from AI-powered machine monitoring technology because it prevents operations interruptions while saving repair expenses, thus resulting in increased factory operational efficiency.

The Internet of Things (IoT) is a modern technology where various physical and virtual devices can be connected and communicate with each other over the Internet often without human intervention (Lee, H. L., et al. 2022). IoT devices are mainly utilized to tackle our everyday problems and to facilitate our life by sensing and collecting various kinds of information about our surrounding physical environment that are utilized to create novel digitized services. The IoT has achieved massive success on an international scale, with billions of devices sold and utilized globally to date across many consumer markets.

The IoT presents substantial advantages for Pakistan's garment sector in addressing issues such as poorly managed supply chains, ageing equipment, and high operational costs (Chakrabarty, 2007). The adoption of smart textile manufacturing represents one major IoT application point, as intelligent systems gather, analyze, and exploit real-time data to benefit factory operations. IoT sensors placed in machinery as well as fabrics and logistics networks enable manufacturers to make their processes more efficient and reduce material waste and maximize resource optimizations (Darian-Smith, 2013). The garment supply chain represents a complex, interdependent logistics system that consists of suppliers, together with fabric processors and distributors, alongside retailers. Pakistan's textile industry manages inventory through manual detection methods, which leads to frequent stockouts combined with surplus stock and supply chain interruptions (Delanty, 2016).

The implementation of IoT-powered inventory management systems enables factories to achieve precise real-time tracking of their fabric moves, material uses, and product deliveries. RFID and barcode tracking systems through IoT let manufacturers track their inventory levels instantly so production aligns with exact market requirements (Dodge, 2020). Tracking technologies employed in manufacturing prevent material shortages and eliminate product stockpiling and minimisation of production outputs (Drache, 2022). IoT-powered automated stock replenishment systems automatically detect when inventory is low and quickly place orders with suppliers, which helps avoid problems in the supply chain.

Through IoT-based inventory optimisation, major global brands, including Nike and Adidas, maintain lean production by manufacturing only what is needed, thus minimising the excess costs of undesired inventory (Fioretos, 2021). Real-time supply chain visibility represents a significant obstacle across Pakistan's garment industry. Delays in fabric delivery, together with shortages of raw materials coupled with inefficient logistics systems, generate missed production deadlines and higher expenses, according to Zhou et al. (2021). Through IoT-powered logistics systems, manufacturers can obtain real-time data about shipments, supplier deliveries, and warehouse storage status, thus ensuring ultimate supply chain component interoperability (Ford, 2023). When manufacturers use tracking GPS and geofencing tools together in IoT settings, they can see the route, get accurate delivery estimates, and get real-time warnings about expected shipping delays. Factory managers receive instant alert notifications in response to delayed shipments and rerouted deliveries (Gonzalez, 2021). The introduction of IoT technology enables new approaches for protecting workers, tracking environmental air quality, and monitoring health protocol compliance (Hyder, 2022).

Smart safety wearables that use IoT technology let biometric sensors track a worker's temperature, activity level, and other health parameters, such as heart rate (Bates et al., 2021). Worker safety wearables track bodily signals to warn employees about developing exhaustion symptoms as well as overheating indicators, which could lead to dehydration or heat stress (Krishnaswamy, 2008). The technology proves crucial for textile dyeing units and weaving mills because it addresses problems associated with high production temperatures (Krisch, 2022). The delivery of IoT technology for air quality monitoring enables textile factories to deploy sensors that monitor carbon dioxide, humidity, and chemicals so facilities maintain safe indoor environments per established international requirements (Lebaron, 2021).

Blockchain technology is a decentralized, distributed ledger system that records transactions across so many computers in a way that makes them immutable and transparent. It allows secure, tamper-proof recording of transactions, with each block in the chain containing a cryptographic hash of the previous block, thus creating an immutable and verifiable record of transactions. (Narayanan et al., 2016). The technology enables maximum transparency that establishes trust with consumers to guarantee sustainable production of ethical garments (Morkunas et al., 2019). Scanning Quick Response (QR) codes on product labels provides consumers

with real-time production information, revealing raw material origins, factory certification records, and employee rights policies (Khan & Qadeer 2021).

Pakistan's textile exporters would improve their market position in international marketplaces and develop regulatory compliance for ethical trade standards of Western and European regions by implementing blockchain-powered ethical verification systems (Morkunas et al., 2019). Because blockchain technology may lessen common issues like labor exploitation and wage violations in developing economies, it maintains worker safety (Iqbal et al., 2019). Workers can receive their money accurately and on time thanks to blockchain-based smart contracts that function in networks to automatically guarantee equitable wage payments (Khan & Qadeer 2021). According to Jamil et al. (2020), the execution of these contracts via blockchain networks safeguards employees through verifiable employment records while preventing computer system failures and unauthorized deductions.

Additionally, supply chains may be digitized and disintermediated thanks to blockchain technology, which can simplify procedures and lower intermediary dependability (Wang et al., 2019). Supply chain operations may become more cost-effective and efficient as a result. Response speeds, safe and secure data, appropriate visibility across nodes, transparent transactions, and supply chain member confidence may all be enhanced by integrating blockchain technology into regular corporate processes (Magd et al., 2023). The financial well-being of small and medium-sized businesses (SMEs) is eventually impacted by the application of blockchain technology and its significant implications for improving supply chain efficiency. Investments in innovation, growth, and resistance to economic unpredictability are made possible by strong financial performance (Conz et al., 2023).

Sustainable supply chain management is the strategic and transparent integration and accomplishment of an organization's social, environmental, and economic goals through the systemic coordination of key inter-organizational business processes in order to improve the long-term economic performance of the individual company and its supply chain. SSCM highlights the need of balancing financial performance with responsibility for society and the environment. (Carter & Rogers, 2008).

With a focus on sustainability, Sustainable Supply Chain Management (SSCM) is a complete and strategic enterprise that includes material, information, and financial capital. By incorporating economic, social, and environmental factors into supply chain operations, the SSCM idea aims to ensure long-term corporate survival and reduce environmental impact. Artificial intelligence (AI), blockchain technology, and the internet of things are just a few of the new technologies that are quickly proliferating and becoming widely used throughout this broader supply chain change. These developments enable businesses to track commodities in real time, optimize logistics based on demand, and guarantee compliance with environmental regulations, eventually reducing waste and gas emissions.

The ability of an organization to achieve and sustain a balance between its long-term social, environmental, and economic objectives is known as sustainable performance. Sustainable performance is defined by the capacity to use resources effectively, reduce environmental effects, and advance social well-being while guaranteeing the attainment of economic viability and profitability. This idea suggests that the three dimensions—financial, social, and environmental—form an essential part of the organization's strategy and operations and are sometimes referred to as the triple bottom line (Elkington, 1998).

Sustainability in the industry is a key factor that determines where a company stands in the global market. Consumers, investors, and policymakers now expect environmentally friendly and morally sound production methods (Govindan et al., 2020). Brands such as H&M, Adidas, and Nike have pledged to achieve 100% sustainable sourcing, thus creating beneficial market opportunities for manufacturers who adopt Industry 4.0 sustainability solutions (Jabbour et al., 2020).

Companies in Pakistan use AI-powered market analytics systems to detect worldwide sustainability patterns while identifying environmentally friendly product trends and adapting their production practices (Bag et al., 2021). Through IoT-enabled, real-time supply chain tracking systems, manufacturers gain the ability to react to disruptions while optimizing logistics and reducing environmental impacts, which leads to enhanced global market opportunities (Wamba et al., 2017). Blockchain technology helps Pakistan be more competitive by allowing full visibility into the supply chain, upholding ethical standards, and ensuring long-term accreditation verification (Sarkis et al., 2021). Proof of sustainable manufacturing through carbon neutrality, fair labour practices, and responsible sourcing enables manufacturers to secure premium trade contracts from sustainability-conscious buyers (Govindan et al., 2020).

The textile sector's speedy transition towards Industry 4.0 requires policymakers, investors, and industry leaders to unite to provide financial support and digital training while stimulating investments in smart factories (Dubey et al., 2019). Pakistan's textile industry can achieve international leadership status in sustainable fashion manufacturing until it overcomes existing technology adoption hurdles (Kshetri, 2018). Smart manufacturing tools, coupled with waste minimization systems and emission monitoring

technologies, allow Pakistan's textile sector to lead sustainable and ethical fashion production (Sarkis et al., 2021). A sustainable competitive future demands digital transformation since managers, investors, and policymakers must position Industry 4.0 adoption at a high strategic level (Jabbour et al., 2020).

Research Framework

This section explains the conceptual and theoretical framework of the research.

Conceptual Framework

This research is intended to examine the impact of artificial intelligence, internet of things and blockchain technology on sustainable performance with in Pakistan's readymade sector with mediating impact of sustainable supply chain management.

Figure 1: Conceptual Framework

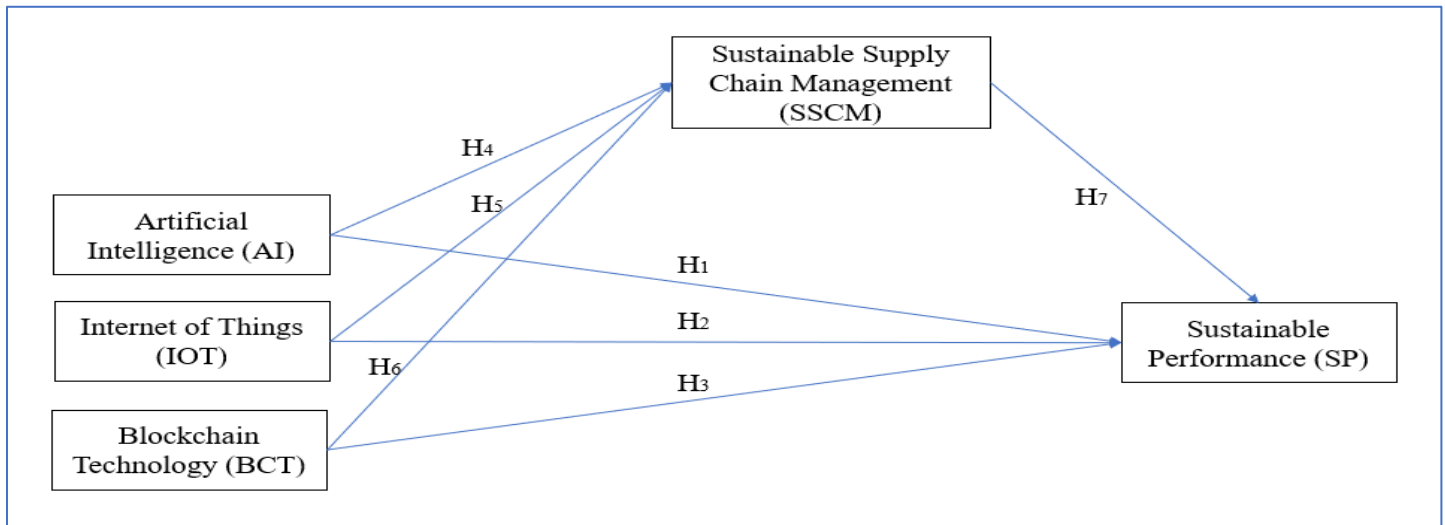


Figure 1 displays the conceptual framework.

Theoretical Framework

This study is founded on the theoretical viewpoints of Tornatzky and Fleischer's (1990) TOE framework, which emphasizes how organizational context, technical preparedness, and external environmental pressure all interact together to influence innovation adoption (Faiz et al., 2024; Sharma et al., 2024). According to current research, the adoption of AI in businesses is influenced by a variety of variables at many levels rather than only technology (Polisetty et al., 2024). According to the theory, organizational, environmental, and technological variables are the three main elements that determine whether or not technological advancements are adopted. These variables specify the aspects that affect change processes as well as the prerequisites for these changes to take place.

Technological features including the technology's perceived benefits, compatibility with current systems, and complexity all play a role in an organization's choice to embrace new technology. The external environmental circumstances, such adherence to international standards, and the internal elements, including company culture and resource sufficiency. The TOE model offers a solid theoretical framework in this situation, enabling a comprehensive analysis of the interplay between internal and external influences.

This research model offers a very solid theoretical foundation.

The following hypotheses have been tested in this research;

SR. No.	Hypothesis
H ₁	AI positively impacts Sustainable Performance.
H ₂	IoT positively impacts Sustainable Performance.
H ₃	Blockchain Technology positively impacts Sustainable Performance.

H ₄	AI positively impacts Sustainable Supply Chain Management.
H ₅	IOT positively impacts Sustainable Supply Chain Management.
H ₆	Blockchain Technology positively impacts Sustainable Supply Chain Management.
H ₇	Sustainable Supply Chain Management positively impact Sustainable Performance.

Research Methodology

The research design used in this study was deductive and cross-sectional. Managers and executives from several clothing enterprises in Punjab, Pakistan, served as the analytic unit for the self-administered survey that was used to collect data from textile and garment workers. To guarantee representativeness, a simple random sample technique was used.

A questionnaire on a five-point Likert scale was used to gather data. Previously established measures were used to evaluate the associations. This questionnaire was adapted from already used sources. Artificial Intelligence (AI) (Qiu, H., et al., 2022), Sustainable Supply Chain Management (Azevedo, S. G., et al. 2023), Blockchain Technology (Treiblmaier, H., et al. 2022), Internet of Things (Lee, H. L., et al. 2022), and Sustainable Performance (Golicic, S. L., et al. 2024).

This study uses a quantitative methodology, using a questionnaire to gather primary data. A representative sample of approx 1000 managers in the clothing industry has been chosen to guarantee the model's statistical power. Cronbach alpha, composite reliability, and other statistical measures retrieved from the data have been used to evaluate the validity and reliability of the results as well as the average variance extracted (AVE). In order to investigate the correlations between the variables and derive significant findings, the gathered data was analysed utilizing sophisticated PLS techniques and specialized software (Ringle et al., 2020).

Results And Analysis

Figure 2 displays the model's partial least squares result. The bootstrapping test was run on the data set acquired in PLS smart in order to determine the statistical significance of PLS-SEM. Figure 3 displays the bootstrapping findings for further analysis.

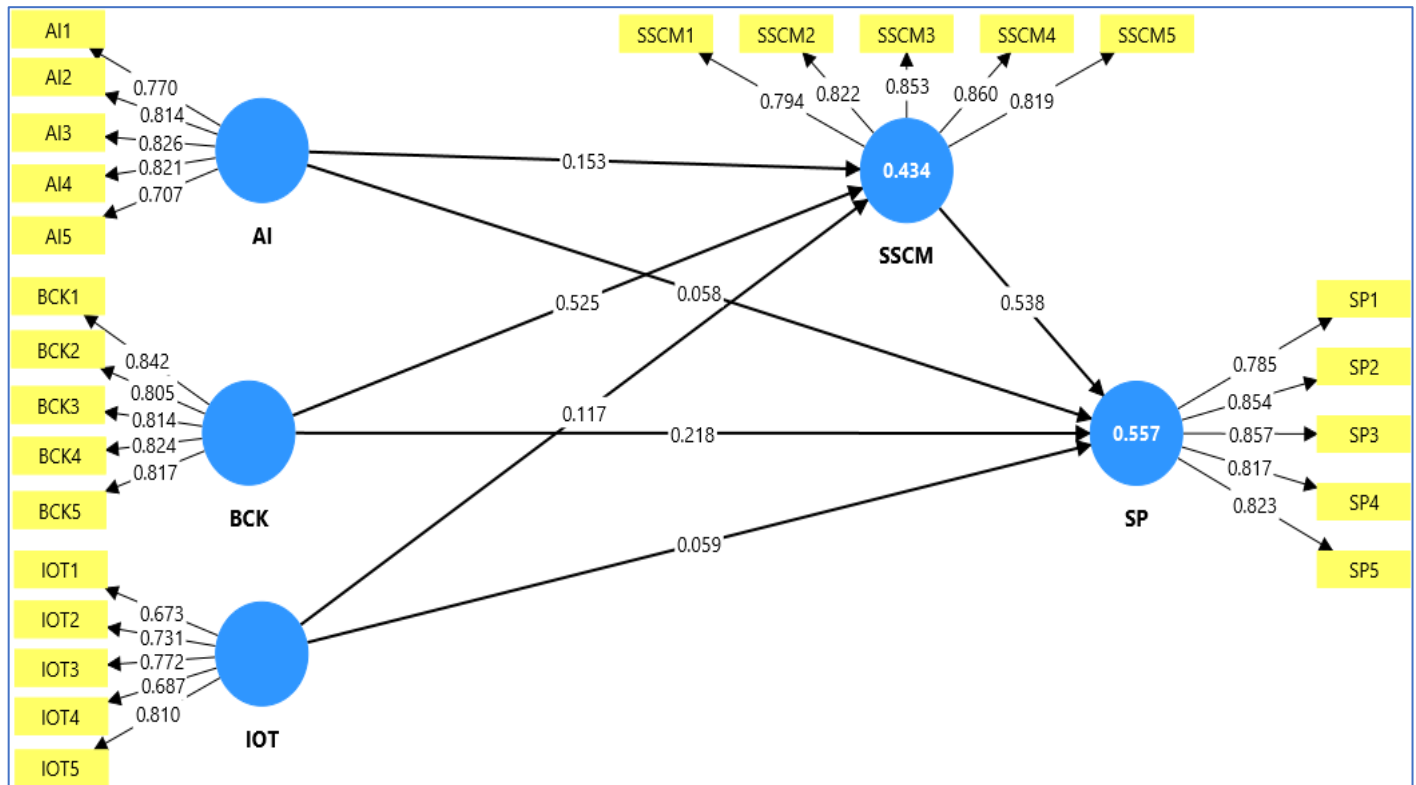


Figure 2: Model Result Using Partial Least Square

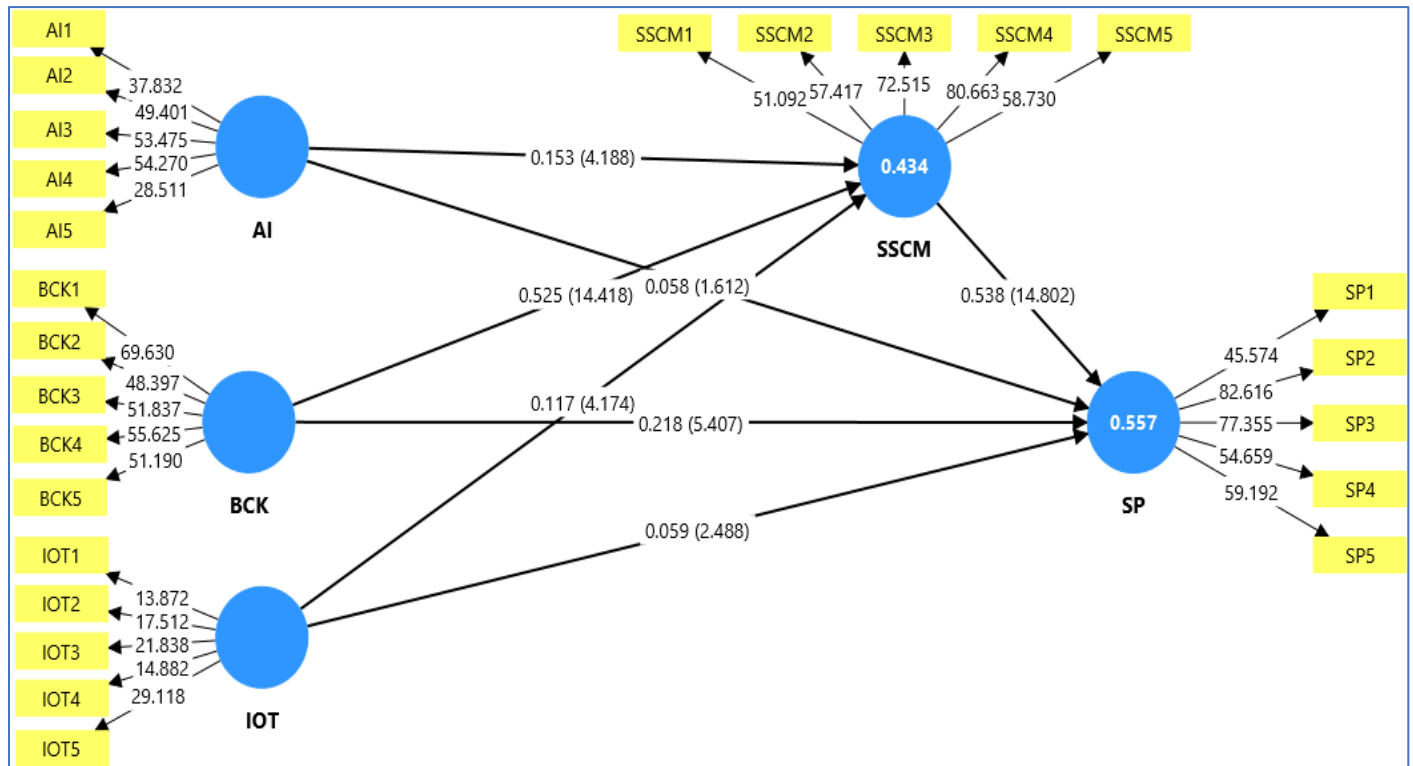


Figure 3: Model Result Using Bootstrapping

The Cronbach alpha value for the analysis is shown in Table 1. The literature states that a Cronbach Alpha score of 0.6 is adequate, meaning that the study's instrument is reliable and suitable for analysis. The dependability of a scale is evaluated using the Cronbach's Alpha coefficient (α) (Ahmed, Q. u. A., Ahmed, A., & Sandhu, K. Y. 2025). The research technique is valid for all of these variables, as the AVE rates for all latent variables are higher than 0.5 as displayed in table 2.

Table 2: Value of Cronbach's alpha

	Cronbach's alpha	Average Variance Extracted (AVE)	Composite Reliability
AI	0.847	0.622	0.891
BCK	0.879	0.673	0.912
IOT	0.792	0.542	0.855
SP	0.885	0.685	0.916
SSCM	0.887	0.688	0.917

The overall dependability of each latent variable can be used to validate an outer model. Table 2 shows how the study affected the reliability of the outer model. The convergent validity of the external model's factor loading rate was ascertained using Tables 3.

Table 3: Factor Loading for Outer Model

	AI	BCK	IOT	SP	SSCM
AI1	0.770				
AI2	0.814				
AI3	0.826				
AI4	0.821				
AI5	0.707				

BCK1	0.842		
BCK2	0.805		
BCK3	0.814		
BCK4	0.824		
BCK5	0.817		
IOT1		0.673	
IOT2		0.731	
IOT3		0.772	
IOT4		0.687	
IOT5		0.810	
SP1			0.785
SP2			0.854
SP3			0.857
SP4			0.817
SP5			0.823
SSCM1			0.794
SSCM2			0.822
SSCM3			0.853
SSCM4			0.860
SSCM5			0.819

When evaluating convergent validity, all of the indicators in Table 3 appear to be reliable.

The Inner Model Goodness-of-Fit test makes use of the R² value. Table 4 shows that AI, IOT, and BCT account for 55.7% of the variation in sustainable performance, indicating moderate to strong explanatory strength. Furthermore, AI and IOT account for 43.4% of the variation, with a range of other factors accounting for the remaining portion.

Table 4: R² Value for Inner Model

	R-square
SP	0.557
SSCM	0.434

The bootstrapping test's processing results are used to validate hypotheses (figure 3). The test was used to decide whether the hypothesis was approved or rejected based on the study's results. Table 6 shows the path coefficient value as well as the outcomes of the t-tests and hypothesis testing.

Table 5: Hypothesis Testing

Hypothesis	Suggested	Path Coefficient	T-Value	Confirmed
H ₁	+	0.058	1.612	REJECTED
H ₂	+	0.059	2.488	ACCEPTED
H ₃	+	0.218	5.407	ACCEPTED
H ₄	+	0.153	4.188	ACCEPTED
H ₅	+	0.117	4.174	ACCEPTED
H ₆	+	0.525	14.418	ACCEPTED
H ₇	+	0.538	14.802	ACCEPTED

As per table 5, AI has positive impact but statistically insignificant so, except H1 all hypothesis was accepted, revealing that all these technologies positively influence the sustainable performance with sustainable supply chain management playing a major role in enhancing sustainability.

Conclusion

The primary objective of this research was to examine the relationship between emerging technologies and sustainable performance within the context of Pakistan's readymade garments industry. From the analysis results, it was revealed that IOT and BCT positively affect sustainable performance meanwhile, the AI has positive but statistically insignificant effect on sustainable performance. We can say that these technologies contribute differently towards sustainable performance.

The current study makes some important theoretical implications to the theory of Technology-Organization-Environment (TOE). Firstly, the research adds value to the TOE technology view by indicating empirically that not all emerging technologies equally contribute to sustainable performance. As Artificial Intelligence fails to contribute significantly, thus indicating that just the technological capability is not enough for achieving sustainability goals. Secondly, this research confirmed the contextual aspect of TOE by doing research in developing country where organizational and technological abilities are in growing stage. Thirdly, this research extends literature regarding digital transformation and sustainable performance by offering a vaster understanding of how emerging technologies explain into performance outcomes.

The current research revealed some practical implication for managers, policy makers and practitioners. Firstly, the most important concern is the right investment and they should invest more in block chain technology and internet of things for monitoring and operations of the industry. Secondly, from analysis results it is confirmed that AI should be strategically implicated along with technologies to get significant results. Thirdly, the policy-makers must create an environment that would support the effective use of digital technologies. Like for in garment sector there should be proper infrastructure and necessary trainings to encourage the use of these technologies.

The research demonstrates that emerging technologies play a major role in sustainable performance where IOT and BCK significantly contribute towards sustainable performance and AI does not show significant effect revealing that the impact of these technologies is not uniform across all domains. This research also enhances the generalizability of TOE based research in emerging economies by focusing on the garment sector of Punjab, Pakistan, where digital transformation is still in its early stages.

References

1. Ahmed, Q. u. A., Ahmed, A., & Sandhu, K. Y. (2025). Artificial intelligence to business performance: A mediation model of technology adoption readiness and corporate governance. *Journal of Asian Development Studies*, 14(2), 1563–1577. <https://doi.org/10.62345/jads.2025.14.2.121>
2. Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, 54(15), 2787–2805.
3. Azevedo, S. G., et al. (2023). *Principles of sustainable supply chain management*.
4. Bag, S., & Kumar, P. (2022). Industry 4.0 and supply chain sustainability: Framework and future research directions. *Resources, Conservation and Recycling*, 178, 106096. <https://doi.org/10.1016/j.resconrec.2021.106096>
5. Bag, S., & Pretorius, J. H. C. (2019). Relationships between industry 4.0, sustainable manufacturing and circular economy: Proposal of a research framework. *International Journal of Organizational Analysis*, 27(3), 218–240. <https://doi.org/10.1108/IJOA-04-2018-1406>
6. Bag, S., Gupta, S. and Pretorius, J.H.C. (2021) 'Role of technology in circular economy: A systematic literature review', *Sustainable Production and Consumption*, 26, pp. 187-202. Available at: <https://doi.org/10.1016/j.spc.2020.09.019>.
7. Bag, S., Gupta, S., & Kumar, S. (2021). Industry 4.0 adoption and 10R advance manufacturing capabilities for sustainable development. *International Journal of Production Economics*, 231, 107830.
8. Bates, M., et al. (2021). Blockchain and supply chain transparency in the garment industry. *Journal of Fashion Technology & Textile Engineering*, 8(3), 115.

9. Bates, T., Khan, Z. and Zhu, Q. (2021) 'Sustainable supply chain management: A review of research and applications', *International Journal of Production Economics*, 231, p. 107843.
10. Boschma, R.A. & Ter Wal, A.L.J., 2007. Knowledge networks and innovative performance in an industrial district: The case of a footwear district in the south of Italy. *Industry and Innovation*, 14(2), pp.177-199.
<https://doi.org/10.1080/13662710701253441>
11. Breschi, S. & Lissoni, F., 2001. Localised knowledge spillovers vs. innovative milieux: Knowledge tacitness reconsidered. *Papers in Regional Science*, 80(3), pp.255-273. <https://doi.org/10.1111/j.1435-5597.2001.tb01799.x>
12. Breschi, S. & Lissoni, F., 2009. Mobility of skilled workers and co-invention networks: An anatomy of localized knowledge flows. *Journal of Economic Geography*, 9(4), pp.439-468. <https://doi.org/10.1093/jeg/lbp008>
13. Carter, C. R., & Rogers, D. S. (2008). A framework of sustainable supply chain management: Moving toward new theory. *International Journal of Physical Distribution & Logistics Management*, 38(5), 360-387.
14. Chakrabarty, D. (2002) *Habitations of Modernity. Essays in the Wake of Modernity*. University of Chicago Press.
15. Chakrabarty, D. (2007) *Provincializing Europe. Postcolonial Thought and Historical Difference*. 2nd edn. Princeton University Press.
16. Chaminade, C., 2011. Are knowledge bases enough? A comparative study of the geography of knowledge sources in China (Great Beijing) and India (Pune). *European Planning Studies*, 19(7), pp.1357-1373. <https://doi.org/10.1080/09654313.2011.573171>
17. Chen, L., Smith, S. and Gupta, J.N.D. (2022) 'Blockchain application in supply chain decarbonization: A literature review', *Journal of Cleaner Production*, 356, p. 131840.
18. Dahlstrom, P., Ewing, M. and Rasmussen, P. (2015) 'The next-generation operating model for the digital world', *McKinsey Quarterly*, 2, pp. 22-35.
19. Darian-Smith, E. (2013) 'Postcolonial Legal Theories of Law'. In R. Banakar and M. Travers (eds), *Law and Social Theory* (2nd edn). Hart Publishing, pp. 247-266.
20. Delanty, G. (2016) 'A Transnational World? The Implications of Transnationalism for Comparative Historical Sociology'. *Social Imaginaries*, 2, pp. 17-34.
21. Dodge, W.S. (2020) 'The New Presumption against Extraterritoriality'. *Harvard Law Review*, 133, pp. 1582-1614.
22. Drache, D. and Froese, M.D. (2022) *Has Populism Won? The War on Liberal Democracy*. ECW.
23. Eder, J., 2018. Innovation in the periphery: A critical survey and research agenda. *International Regional Science Review*, 42(2), pp.119-146. <https://doi.org/10.1177/0160017618764279>
24. Edquist, C., 2019. Towards a holistic innovation policy: Can the Swedish National Innovation Council (NIC) be a role model? *Research Policy*, 48(4), pp.869-879. <https://doi.org/10.1016/j.respol.2018.10.008>
25. Eghbal, D., Davaie-Markazi, K., Keshmiri, A., Pakseresht, H., Kiarasi, M. & Ooshani, N., 2017. Development of oil and gas areas of innovation in Iran. Presented at the IASP World Conference, Istanbul, Turkey.
26. Elkington, J. (1998) *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*. Gabriola Island: New Society Publishers.
27. Fioretos, O. and Tallberg, J. (2021) 'Politics and Theory of Global Governance'. *International Theory*, 13, pp. 99-118.
28. Ford, M., Gillan, M. and Ward, K. (2023) 'Beyond the Brands: COVID-19, Supply Chain Governance, and the State-Labor Nexus'. *Industrial Relations*, 62, pp. 172-175.
29. Gertler, M.S. & Levitte, Y.M., 2005. Local nodes in global networks: The geography of knowledge flows in biotechnology innovation. *Industry and Innovation*, 12(4), pp.487-507. <https://doi.org/10.1080/13662710500361981>

30. Golubic, S. L., et al. (2024). *Linking sustainability and financial performance in supply chains*.
31. Gonzalez, C.G. (2021) 'Racial Capitalism, Climate Justice, and Climate Displacement'. *Oñati Socio-Legal Series*, 11, pp. 108–130.
32. Govindan, K., Soleimani, H. and Kannan, D. (2020) 'Sustainability performance in the supply chain: An integrated approach', *Transportation Research Part E: Logistics and Transportation Review*, 87, pp. 161-176. Available at: <https://doi.org/10.1016/j.tre.2019.06.003>.
33. Hyder, S. (2022) 'Unsettling Feminist Geopolitics: Forging Feminist Political Geographies of Violence and Displacement'. *Gender, Place & Culture: A Journal of Feminist Geography*, 26(1), pp. 3–6.
34. International Labour Organization (ILO). (2020). *Labor conditions in the garment industry*. ILO Publications.
35. Iqbal, M., et al. (2019). Blockchain technology and its applications to combat counterfeiting in the textile industry. *Textile Research Journal*, 89(14), 28512862.
36. Iqbal, M.W., Hu, H. and Zhu, L. (2019) 'Effect of green procurement practices on sustainable performance: Evidence from Pakistani construction industry', *Journal of Cleaner Production*, 236, pp. 117-129.
37. Jabbour, C.J.C., Jabbour, A.B.L., Sarkis, J. and Govindan, K. (2020) 'Understanding the synergistic effects of Industry 4.0 technologies on sustainable supply chains: A review', *Journal of Cleaner Production*, 243, p. 118563. Available at: <https://doi.org/10.1016/j.jclepro.2020.118563>.
38. Jamil, F., et al. (2020). Towards block chain enabled supply chain for textile and clothing industry. *Journal of Cleaner Production*, 244, 118643.
39. Jamil, R.A., Qadeer, F. and Khan, M.A.S. (2020) 'Impact of transformational leadership on employee voice behavior in the telecom sector of Pakistan: The mediating role of psychological empowerment and moderating role of procedural justice', *Cogent Business & Management*, 7(1), p. 1722463.
40. Kamble, S. S., Gunasekaran, A., &Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection*, 117, 408-425. <https://doi.org/10.1016/j.psep.2018.05.009>
41. Khan, M., & Qadeer, F. (2021). Blockchain for traceability in garments industry: A roadmap for Pakistan. *Journal of Cleaner Production*, 295, 126333.
42. Khan, S.A.R. and Qadeer, F. (2021) 'A systematic literature review on green supply chain management: Research implications and future perspectives', *International Journal of Logistics Research and Applications*, 24(6), pp. 605-625.
43. Krisch, N. (2022) 'Jurisdiction Unbound: (Extra)territorial Regulation as Global Governance'. *European Journal of International Law*, 33, pp. 481–504.
44. Krishnaswamy, R. and Hawley, J.C. (2008) (eds.) *The Postcolonial and the Global*. University of Minnesota Press.
45. Kshetri, N. (2018) 'Blockchain's roles in meeting key supply chain management objectives', *International Journal of Information Management*, 39, pp. 80-89. Available at: <https://doi.org/10.1016/j.ijinfomgt.2017.12.005>.
46. Lee, H. L., et al. (2022). *The role of IoT in enhancing supply chain transparency*.
47. Lee, S., & Lim, S. (2020). Innovation through R&D activities in the pharmaceutical industry: An analysis of the US market. *Journal of Business Research*, 109, 366373.
48. Lee, S.M. and Lim, S. (2020) 'Blockchain and supply chain management: A new paradigm for supply chain integration and collaboration', *Operations Management Research*, 13(1-2), pp. 13-25.
49. Morkunas, V.J., Paschen, J. and Boon, E. (2019) 'How blockchain technologies impact your business model', *Business Horizons*, 62(3), pp. 295-306.

50. Narayanan, A., Bonneau, J., Felten, E., Miller, A., & Goldfeder, S. (2016). *Bitcoin and Cryptocurrency Technologies*. Princeton University Press.
51. Pakistan Apparel Forum. (2021). *Pakistan apparel forum*. Retrieved from <https://pakistanapparelfourm.com/>
52. Pereira, A.C. and Romero, F. (2017) 'A review of the meanings and the implications of the Industry 4.0 concept', *Procedia Manufacturing*, 13, pp. 1206-1214.
53. Qiu, H., et al. (2022). *The impact of AI on supply chain management: A systematic review*.
54. Qiu, H., Zhang, T., & Yu, W. (2022). Artificial Intelligence in supply chain management: Applications and implications. *Journal of Business Research*, 140, 461-475.
55. Rehman, A., et al. (2022). Barriers to Industry 4.0 adoption: Insights from emerging economies. *Journal of Global Operations*, 13(3), 215-233.
56. Rehman, H., Zhao, M., Ashfaq, M., & Ahmad, N. (2022). A review of Industry 4.0 in supply chain: Implications for sustainability risk management in the fashion industry. *Journal of Cleaner Production*, 319, 128759.
57. Russell, S., & Norvig, P. (2021). *Artificial Intelligence: A Modern Approach*. Pearson.
58. Seuring, S. and Müller, M. (2008) 'From a literature review to a conceptual framework for sustainable supply chain management', *Journal of Cleaner Production*, 16(15), pp. 1699-1710.
59. State Bank of Pakistan. (n.d.). *Role of textile industry in the economy*. Retrieved from <https://www.sbp.org.pk/>
60. Tornatzky, L., & Fleischer, M. (1990). *The Processes of Technological Innovation*. Lexington Books.
61. Treiblmaier, H., et al. (2022). Blockchain in supply chains: Enhancing traceability and transparency. *Logistics and Transportation Review*, 98, 102913.
62. Zhou, K., et al. (2021). *Internet of Things in Industries: A Survey*. *IEEE Transactions on Industrial Informatics*, 17(11), 77477768.
63. Zhou, W., Chong, A.Y.L. and Ngai, E.W.T. (2021) 'Supply chain management in the era of Industry 4.0: Concepts, frameworks, and applications', *International Journal of Production Economics*, 232, p. 107965.
64. Zhu, Q., Sarkis, J. and Lai, K.H. (2012) 'Examining the effects of green supply chain management practices and their mediations on performance improvements', *International Journal of Production Research*, 50(5), pp. 1377-1394.



2026 by the authors; Journal of Global Social Transformation (JGST). This is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC-BY) license (<http://creativecommons.org/licenses/by/4.0/>).