



Impact of Green Innovation Strategy and Digital Transformation on Sustainable Firm Performance with Mediating Role of GSCM Practices: An Empirical Investigation with PLS-SEM Modeling

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ABSTRACT

The purpose of this research is to investigate the synergistic impacts of green supply chain management (GSCM) on green innovation strategy and digital transformation on sustainable performance. This is done in the context of the growing need for businesses to find a balance between sustainable development and digital transformation. PLS-SEM is used to evaluate the model, and the data used for the evaluation comes from a questionnaire survey that was sent out to manufacturing firms in Pakistan. Data was collected from 411 respondents. By examining and considering the role that green supply chain management (GSCM) plays as a mediator in the link between green innovation strategy and digital transformation on sustainable performance, the present research makes a contribution to the existing body of information on innovation and sustainability. Additionally, it adds to the development of new understanding about the mediating influence of GSCM practices on the interaction between green innovation strategy and digital transformation on sustainable performance, especially in the context of an economy that is still in the process of evolving. Both those who formulate policy and those who are in charge of administration at manufacturing firms will find that the ramifications of this research are significant. They may be used as a foundation for the creation of more efficient strategies and policies that will boost the capacities of businesses to produce innovations that might minimize environmental hazards and other negative consequences of climate change. These inventions could be used to mitigate the effects of climate change.



Introduction

The severe impact of environmental degradation, which has been exacerbated by the advances in industrialization over the years, is eroding the global socio-economic prosperity. The ecological burden associated with construction has had an unprecedented impact on the biodiversity of the Earth. In particular, the dual environmental influence on both social and commercial life has exacerbated the necessity of identifying a solution to the evolving socio-ecological issues (Akram et al., 2025a). The escalating environmental pressure has had a substantial impact on the social foundations of the world, with the sustainability of enterprises playing a significant role in addressing the emerging ecological challenges (Kouser et al., 2025). It is unsurprising that the world's primary industries have been confronted with severe environmental consequences as a consequence of the escalating environmental degradation. In response to the ecological decline that has become a global phenomenon, stakeholders have adopted a sustainable model in response to the expanding climatic vulnerability (Watto et al., 2025). The preservation of the natural environment has been a global priority in recent years. Organizations have been obligated to implement sustainable innovation strategies in order to protect the environment in response to environmental regulations (Asadullah et al., 2025).

The sustainability model has been significantly affected by the environmentally conscious behaviors of employees, as the enterprise's prosperity and well-being are now based on GI strategies. The primary constituents of a company are its personnel, who significantly impact its sustainable performance. Employees are encouraged to participate in environmental protection initiatives by their tangible GI actions, including the preservation of the motherland (Akram et al., 2025b) (Afum et al., 202). The research suggests that these ecological prevention concerns have incited employees to implement the necessary measures, thereby promoting sustainable environmental performance (AiY.-H et al., 2021).

The business world is transitioning to digitization in the early years of the 21st century as the world undergoes the fourth industrial revolution. The digital transformation required to achieve "industry 4.000" has rapidly garnered widespread recognition in the industrial, academic, and governmental domains worldwide since its introduction in 2011 (Baah et al., 2020). The business strategies of manufacturing firms are being revolutionized by the emergence of industry 4.0. The incorporation of a diverse array of sophisticated communication, informational, and intelligent technologies enhances the flexibility, efficiency, and output of manufacturing (Awan et al., 2021). Industry 4.0 is a modern manufacturing system that is dependent on information technology and is essential for the advancement of sustainable development in society, as defined by Watto, W. A. (2024). Consequently, there is an increasing emphasis on the significant contributions of industry 4.0 to the economic, environmental, and social aspects of sustainability and the impact of industry 4.0 on sustainable development. Scholars are currently concentrating on the topics of sustainable development in enterprises and industry 4.0 digital technology in this context. For example, Ameer and Khan (2022) conducted their most recent research on the influence of antecedents on the sustainable performance of organizations and industry 4.0. Moreover, Asadi, S., OmSalameh Pourhashemi, S., Nilashi, M., Abdullah, R., Samad, S., Yadegaridehkordi, E., Aljojo, N., and Razali, N. S. (2020) investigated the sustainable performance of Pakistani manufacturing firms in the industry 4.0 era, as well as the current public economic trends and technological challenges. Therefore, it is evident that this research topic is on the brink of a successful trend; however, additional research is required to determine the precise mechanisms of impact in a diverse array of industries and cultural contexts.

Industry 4.0 has transformed the manufacturing sector by introducing innovative technologies that optimize resource utilization to achieve optimal output (Kamble, Gunasekaran, & Gawankar, 2018). By improving resource efficiency, the implementation of industry 4.0 has the potential to significantly improve sustainable industrial value creation in the social, economic, and environmental domains, as per Sharma, Jabbour, and Lopes de Sousa Jabbour (2021). Digital transformation has disrupted conventional methodologies of production and operational management by seamlessly integrating intelligent technologies into the manufacturing industry. The development of more effective products, increased production efficiency, and superior customer service has been facilitated by this (Neuhofer, Buhalis, & Ladkin, 2015). Furthermore, these state-of-the-art technologies have the potential to enable the efficient allocation of resources, thereby releasing the full potential of environmental sustainability (Dubey et al., 2019). However, some academics have expressed a different perspective, arguing that digital technologies may have unintended negative repercussions on sustainable development (Lopes de Sousa Jabbour, Jabbour, Godinho Filho, & Roubaud, 2018).

This is a consequence of the potential for emergent technologies to exacerbate competitive dynamics in the corporate sector and impose financial and environmental pressures on manufacturing firms (Khan et al., 2021; Khan, Idrees, & Haider, 2023). Consequently, industry 4.0 is not sufficiently assessed from a sustainability perspective, despite the fact that a substantial number of academics (Beier, Niehoff, Ziems, & Xue, 2017) argue that it is a catalyst for sustainable progress (Sharma et al., 2021). A comprehensive analysis of the comprehensive nexus between digital technologies and the performance related to sustainable development, which integrates economic and environmental aspects, has not yet been conducted.

The integration of environmental concerns and logistics administration has evolved into a prospering subfield over the past two decades (Sarkis, 2012). Although the green supply chain has been acknowledged as a critical element of sustainable logistics management, there are still a number of aspects that necessitate further investigation, particularly in developed nations where eco-friendly supply chain management has been experiencing a surge. The research suggests that companies have the potential to improve their sustainability performance by implementing green supply chain management (GSCM) strategies and effectively utilizing digital technology. Previous research has acknowledged the substantial influence of Industry 4.0's advanced digital technologies on supply chain relationships. According to Khan, Idrees, and Haider (2023), green supply chains are still well-received because they have the potential to enhance a company's image, which in turn leads to increased revenue, cost reductions, and monetary value. In order to promote sustainable development, it is advised that manufacturing corporations implement environmentally friendly practices in their supply chain management.

As a result, this study examines the influence of digital technologies on the sustainable performance of businesses in the new era of industry 4.0, with the goal of cultivating an environmentally cognizant and sustainable business environment. The research is founded on the practice-based view (PBV) theory and information processing theory (IPT). Furthermore, this investigation will assess. As a result, this investigation aims to rectify this deficiency and proposes the subsequent research objectives.

1. Investigate the correlation between sustainable performance and digital transformation.
2. Investigate the correlation between sustainable performance and green innovation strategy.
3. Investigate the correlation between green supply chain management practices and digital transformation.

4. Examine the correlation between sustainable performance and green supply chain management practices;
5. Evaluate the relationship between green innovation strategy and green supply chain management practices.
6. Assess the degree to which green supply chain management practices have a substantial impact on sustainable performance, green innovation strategy, and digital transformation.

Literature Review

Digital transformation and sustainable performance

Digital transformation has the potential to enhance the efficiency of virtually any organizational routine or business activity (Warner and Wager, 2019). However, there is evidence to suggest that the extent of this influence and its impact on performance varies among firms. Vial (2019) has found evidence that organizations are unable to accomplish their objectives when they begin a digital transformation process. To effectively compete in a world that is becoming increasingly digital, the organization must implement processes and procedures that facilitate digital transformation. This necessitates a substantial allocation of a variety of resources, such as financial resources and skilled personnel (Gong and Ribiere, 2021). Furthermore, the organization must surmount organizational inertia and employee resistance to change (Singh and Hess, 2017). As a result, innovative SMEs must efficiently and effectively implement these practices in order to recoup these investments in terms of firm performance (Goerzig and Bauernhansl, 2018). This is due to the expenses associated with investing in new digital technologies (Ceipek et al., 2021) and the challenges associated with establishing a robust digital culture (Vial, 2019). We have identified three distinct mechanisms through which the performance of innovative SMEs is positively correlated with digital transformation. Finally, digital transformation can provide businesses with the opportunity to improve operational efficiency and establish more robust synergies among their diverse business processes. For instance, digital transformation facilitates the more efficient exchange of information within organizations (Frank et al., 2019) and the more cost-effective transportation of tangible goods (Li et al., 2017). As a result, Sustainable Performances should be more profitable by reducing the costs. Consequently, in light of the aforementioned arguments, we propose the following hypothesis.

H1. Digital transformation is positively related to Sustainable Performance.

Green innovation strategy and sustainable performance

The impact of climate change has become increasingly evident as environmental issues have continued to escalate. Companies have implemented green strategies to achieve sustainable performance in response to these abrupt socio-environmental shifts. Green innovation strategy is a prevalent method for reducing the superfluous climatic burden (Singh et al., 2020). Companies have altered their innovation strategies to enhance their sustainable performance, emphasizing the significance of reducing their ecological footprint (Yusliza et al., 2020). The production process of firms is improved by the stimulation of a Green innovation strategy. In essence, it mitigates the operational impact of the organization as a result of contamination. Sun et al. (2020) argue that sustainability requires organizations to develop environmentally friendly strategies in order to preserve the current environment. This is the basis of their clarification of the concept. In recent years, Green innovation strategy have garnered significant research attention (Zhou et al., 2019) by providing innovative pathways to long-term stability. The organization recognizes the importance of sustainable performance as a result of the strategies of the firms (Musaad O et al., 2020). By adhering to socio-ecological standards, it allows enterprises to satisfy stakeholders' requirements.

Consequently, the research implies that the implementation of innovative practices is a method by which a green strategy mitigates the effects of environmental degradation (Singh et al., 2020). A multiplicity of enterprises has implemented environmentally responsible strategies as a novel approach to enhance their operations in response to the increasing significance of Green innovation strategy. The research indicates that organizations have been compelled to adopt green strategies in order to guarantee sustainable operations as a consequence of the growing environmental concerns (Ameer & Khan, 2022; Zhang et al., 2020). Scholars have previously identified green innovation strategy development instrument that enhances the sustainable performance of firms in the literature. Consequently, the hypothesis that follows is predicated on the current analysis and the existing literature:

H2: Green innovation strategy has a positive and significant impact on sustainable performance

Digital transformation and green supply chain management (GSCM)

Substantial evidence has been accumulated regarding the advantages of digital technology in the pursuance of ecological sustainability and the implementation of eco-friendly supply chains through extensive research (Lucas Jr and Goh, 2009). The procurement sector's utilization of digital technology has been extensively documented by a multitude of authors. These benefits include improved detection of raw materials, reduced inventory, optimized replenishment processes, increased flexibility in procurement processes, and enhanced quality monitoring and control (Nasiri et al., 2020). Digital technology facilitates the seamless integration and communication of production systems, thereby enhancing the efficiency, flexibility, and capacity to respond swiftly to fluctuations in demand (Pagani, 2013). Furthermore, digital technology has the capacity to modify environmental parameters, including energy efficiency, greenhouse gas emissions, resource consumption, toxicity, and refuse generation, by enabling the real-time optimization of manufacturing processes (Colovic, 2022). Additionally, there are numerous academics who contend that the digitization of supply chains has a beneficial impact on environmentally responsible logistics. For example, the identification, monitoring, and recording of products and materials are significantly influenced by Internet of Things (IoT) technologies, including barcodes, sensors, global positioning systems, and radio frequency identification (RFID) (Goerzig and Bauernhansl, 2018). Karimi and Walter (2015) assert that the circular economy and digital technology are unambiguously and directly correlated. The empirical evidence presented by Schlalmo et al. (2017) regarding the impact of IoT solutions on the administration of reverse supply chains was derived from their examination of refuse metal producers. Furthermore, (Urbinati et al., 2019) underscored that the implementation of RFID systems has enhanced the quality and availability of separation and inspection processes, alleviated information gaps in recycling networks for reverse logistics, and enhanced supply reliability. In consideration of these viewpoints, the subsequent hypothesis is put forth:

H3. Digital transformation has a positive, direct effect on GSCM practices.

Green innovation strategy and green supply chain management (GSCM)

The efficacy and cultivation of fundamental competencies of companies can be enhanced through the successful implementation of a Green Innovation strategy (Wu et al., 2021). In order to increase its significance, the subject of businesses' adoption of green innovation strategy and implementation of green supply chain management (GSCM) practices in the value chain can be considered (Zhao et al., 2021). There is a strategic relationship between Green Innovation strategy and Green Supply Chain Management (GSCM) due to the significance of the product life cycle (Ding et al., 2024). The relationship between two remarkable topics has been the subject of

numerous studies: Liu (2022) investigates the literature regarding green supply chain management (GSCM) practices and green innovation strategies. (Zhao et al., 2021) examine the theoretical relationship between Green Innovation strategy and GSCM. A positive and direct relationship between Green Innovation strategy and Green supply chain management (GSCM) practices is established by another study (Fernandez-Portillo et al., 2022). Additionally, Green Innovation strategy I serves as a mediator in the relationship between EP and green supply chain management (GSCM) practices. In the conceptual model of the research, the relationship between three variables, namely Green supply chain management (GSCM) and Green Innovation strategy, as determined by Purwanto et al. (Zhao et al., 2021), is investigated. The research concluded that Green Supply Chain Management (GSCM) has a beneficial impact on the Green Innovation strategy. In this regard, the initial hypothesis of the research is as follows, as indicated by the pertinent literature:

H4. Green Innovation strategy has a positive impact on green supply chain management (GSCM)

Green supply chain management (GSCM) and sustainable performance

As a result, the optimization of GSCM processes promotes environmental sustainability, reduces the depletion of natural resources, and reduces the use of extraneous materials by improving the efficient utilization of resources and materials (Ni & Liu, 2021). This results in a reduction in production costs and an increase in sales and profits (Qi & Xiao, 2020). In addition, the incorporation of digital technology has led to an increase in market share and sales, the acceleration of product development and pricing optimization, the improvement of demand forecasting and production planning, and the enhancement of customer service (Verhoef et al., 2021). GSCM not only enhances energy efficiency but also reduces carbon emissions, in addition to extending the lifespan of products (Vial, 2019). Eco-friendly practices have the potential to improve the work environment for employees, thereby increasing their perception of well-being (Caputo et al., 2021). Consequently, the integration of GSCM into the operational strategies of organizations may lead to Sustainable Performance outcomes that are advantageous. The available evidence indicates that eco-friendly initiatives are crucial for the following: fostering customer loyalty, enhancing corporate reputation (Vial, 2019; Verhoef et al., 2021), improving public health, promoting equal opportunities, ensuring product safety and workplace conditions, and adhering to legal and ethical standards (Ni & Liu, 2021). Despite the scarcity of empirical research on the relationship between GSCM practices and Sustainable Performance, the evidence suggests that such initiatives are essential. In consideration of these factors, the subsequent hypotheses are put forth:

H5. Green supply chain management (GSCM) has a direct positive impact on sustainable performance

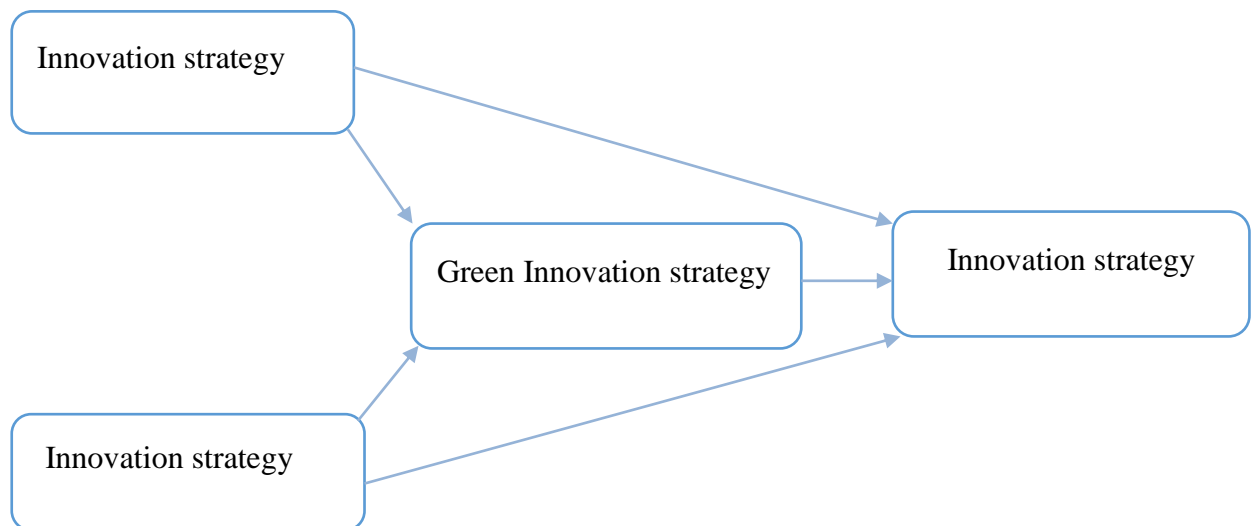
Mediation of GSCM between digital transformation and sustainable performances

Organizations can effectively address market volatility and optimize environmentally conscious manufacturing processes and eco-friendly product development by integrating digital technology into the tangible components of the supply chain (Li et al., 2021). This method has the potential to enhance the ecological performance of organizations and provide them with a competitive advantage. The implementation of Industry 4.0 technology facilitates the interlinking and digitalization of procedures, products, and services (Li et al., 2016). This generation of real-time data improves resource planning (Xie & Breen, 2012), environmental monitoring, and supply chain synchronization (Rehman Khan & Yu, 2021). The antecedent sections advanced the hypothesis that sustainable performance is considerably and advantageously influenced by GSCM practices,

which are in turn significantly and advantageously influenced by digital technologies. This process is acknowledged as being mediated by GSCM practices as a result. In a recent study conducted by Umar, Khan, Zia-ul-haq, Yusliza, and Farooq (2022), GSCM practices were successfully validated as a mediating factor in the relationship between industry 4.0 and the environment and economic performance. The implementation of industry 4.0 technologies facilitates the adoption of GSCM practices and the improvement of their internal data processing capabilities (Li et al., 2020). Sony and Naik's (2019) research illustrates that the effectiveness of supply chain operations is enhanced by the facilitation of the integration of practical and manifest data through the use of digital technologies. This technological innovation enhances the efficiency of decision-making throughout the entire inventory network and encourages collaboration and engagement with supply chain partners. The substantial influence of GSCM practices on the improvement of societal, economic, and environmental performance is also demonstrated in pertinent literature (Rajeev, Pati, Padhi, & Govindan, 2017). As a result, we propose the following research hypothesis.

H6. GSCM practices mediate the relationship between digital transformation and sustainable performances.

H7. GSCM practices mediate the relationship between green innovation strategy and sustainable performances.



Methodology

The purpose of this research is to investigate the synergistic impacts of green supply chain management (GSCM) on green innovation strategy and digital transformation on sustainable performance. The quantitative approach was implemented, and data was collected through a questionnaire survey. A convenience sampling procedure was implemented to collect data from the personnel of the Pakistani manufacturing sector. The manufacturing sector was selected due to its exposure to public environmental concerns and governmental regulations. Consent was obtained from all study participants prior to the survey's implementation. The target population consists of the administrators and personnel of manufacturing companies that have implemented green innovation strategy and digital transformation. The response rate was 82%, with 460 questionnaires having been returned from the 500 that were distributed to respondents. It was determined that 411 of these were valid and functional. In order to evaluate the common method

bias, Harman's single factor approach was implemented. This investigation is clear of common method bias, as the variance of a single factor is 8.555% or less.

The 5-item scale from Proksch et al. (2024) was employed to evaluate digital transformation, while the 3-item scale was employed to evaluate green innovation strategy. Su et al. (2020) conducted research that served as the foundation for the development of the measurement elements scale. In the study conducted by Rajeev, Pati, Padhi, and Govindan et al. (2017), the 5-item scale was employed to evaluate the moderating variable, green supply chain management (GSCM). The 5-item scale from Gelhard and Von Delft (2016) was implemented to evaluate sustainable performance.

The demographic information of the study participants, including their gender, age, education, and status, is summarized in Table 1. Demographic Information: Table 1

Table 1: Demographic information

Category	Sub-category	Frequency	Percent
Gender	Female	143	54.2%
Gender	Male	121	45.8%
Age	21-25	112	42.4%
Age	26-30	138	52.3%
Age	31-35	12	4.5%
Age	36-40	2	0.8%
Education	Intermediate	46	17.4%
Education	Bachelors	55	20.8%
Education	Masters	94	35.6%
Education	M. Phil	60	22.7%
Education	PhD	9	3.4%
Total		264	100.0%

Method of measurement

The structural components and measurement data of the models were analyzed using the partial least square structural equation modeling (PLS-SEM) technique using the Smart PLS program (Ringle, 2005) (Hair et al., 2013). The methodology's coherence validity has been assessed. The construct validity evaluates the extent to which a diverse array of items accurately represents the same subject. In order to assess convergent validity, factor loadings, composite reliability (CR), and average variance extracted (AVE) were implemented. The CR is recommended to be 0.7, and the AVE is recommended to be 0.5. The loadings are configured to be 0.5 by default. The PLS analysis indicated that the construct of Digital Transformation was considered a second-order construct in the current study. Table 2 illustrates that the outcomes of the measurement model are superior to those that were initially proposed (Hair et al., 2013). This implies that the convergence validity was adequate. The validity of the four constructs was determined by evaluating the convergent validity of each individual construct using the standardized factor loadings (Sellbom & Tellegen, 2019). According to the findings, the loadings of each of the reflected indicators exceeded the minimum threshold of 0.50, with a range of 0.667 to 0.971. The convergent reliability of each construct was demonstrated by a factor loading on that construct that exceeded 0.50. This demonstrated the validity of each construct examined in this paper (Hair et al., 1998; Sellbom &

Tellegen, 2019). Additionally, Hair et al. (1998) assessed the discriminant validity of each concept by employing the AVE. The AVE ranged from 0.638 to 0.833.

Table 2: Measurement model

1st order concepts	Items	Loadings	CR	AVR	Cronbach's α
Digital Transformation	DT1	0.812	0.740	0.659	0.723
	DT2	0.821			
	DT3	0.832			
	DT4	0.823			
	DT5	0.840			
Green innovation strategy	GIC1	0.800	0.783	0.695	0.783
	GIC2	0.810			
	GIC3	0.845			
Green supply chain management (GSCM)	GSCM1	0.854	0.774	0.705	0.769
	GSCM2	0.867			
	GSCM3	0.807			
	GSCM4	0.845			
	GSCM5	0.802			
Sustainable Performance	SP1	0.856	0.751	0.710	0.790
	SP2	0.845			
	SP3	0.832			
	SP4	0.854			
	SP5	0.845			

Table 3 of the method of (Fornell & Larcker, 1981) is employed to ascertain the discriminant validity of a construct. Discriminant validity refers to the degree to which a single item can differentiate between concepts or assess distinct constructs. The corresponding correlations were compared to the square root of AVE or squared correlations. The discriminating validity of the AVE was illustrated by the fact that the square root of the AVE between each pair of factors was greater than the correlation computed between factors (Cheah et al., 2021; Hair et al., 2013). Compared to other indicators in the same column and row, an indicator's loadings are higher for the same construct. This demonstrates the indicator's discriminant nature.

Table 3: Discriminant validity

	Digital Transformation	Green innovation strategy	Green supply chain management (GSCM)	Sustainable Performance
Digital Transformation	0.815***			
Green innovation strategy	0.756**	0.874***		
Green supply chain management (GSCM)	0.665***	0.695***	0.822***	
Sustainable Performance	0.740***	0.665**	0.668**	0.875***

Structural equation modeling

The structural model and assumptions were validated using the Smart PLS 4.0 software (Ringle, 2005).The estimation of the measurement model was finalized, and PLS-SEM was subsequently demonstrated (see figure 2).R2 was created to assess the structural model's predictive capabilities.R2 is an explanatory metric that assesses the degree to which the observed variance can be attributed to exogenous factors (Hair et al., 2012, 2013).

The hypothesis (H1) was effectively supported, as the quality of Sustainable Performance was substantially and positively correlated with Digital Transformation ($\beta = 0.554, p = 0.000, t = 2.051$) (Table 4).Additionally, the H2 was substantiated by the substantial and positive correlation between Sustainable Performance and Green Innovation Strategy ($\beta = 0.657, p = 0.000, t = 2.438$).

In addition, the Green Supply Chain Management (GSCM) was positively correlated with the Sustainable Performance ($\beta = 0.338, p = 0.040, t = 2.051$); as a result, H3 was accepted..

Table 4 demonstrates a substantial positive correlation between digital transformation and green supply chain management (GSCM) ($\beta = 0.264, p = 0.000, t = 3.006$); as a result, H4 was maintained. In addition, the Green innovation strategy is significantly correlated with Green supply chain management (GSCM) ($\beta = 0.134, p = 0.001, t = 2.006$); consequently, H5 is accepted.

Table 4 demonstrates that a substantial positive correlation exists between Sustainable Performance and Digital Transformation, which is mediated by green supply chain management ($\beta = 0.234, p = 0.001, t = 2.045$). This resulted in the endorsement of H6.

Table 4 demonstrates that a substantial positive correlation exists between Sustainable Performance and Digital Transformation, which is mediated by green supply chain management ($\beta = 0.432, p = 0.005, t = 2.006$). This resulted in the endorsement of H7.

Table 4: Structural modeling and medeation analysis

Direct effect				
Variables	Path coefficient	SD	t-value	p value
Digital Transformation -> Sustainable Performance	0.554	0.340	2.051	0.001
Green innovation strategy -> Sustainable Performance	0.657	0.239	2.438	0.004
Green supply chain management (GSCM) -> Sustainable Performance	0.338	0.450	2.051	0.035
Digital Transformation ->Green supply chain management (GSCM)	0.264	0.340	3.006	0.000
Green innovation strategy ->Green supply chain management (GSCM)	0.134	0.982	2.006	0.004
Medeation analysis				
Paths	Path coefficient	SD	t-value	p value
Digital Transformation ->Green supply chain management (GSCM)-> Sustainable Performance	0.234	0.450	2.045	0.001
Green innovation strategy ->Green supply chain management (GSCM)-> Sustainable Performance	0.432	0.095	2.006	0.005

Discussion

The purpose of this research is to investigate the synergistic impacts of green supply chain management (GSCM) on green innovation strategy and digital transformation on sustainable performance. First, we found that digital transformation improves businesses' green supply chain management (GSCM) and sustainable performance. Unquestionably, empirical study on how digital revolution affects eco-friendly activities is still in its infancy. The integration of technological resources with human resource management requires the creation and application of HRM strategies that are directly based on digital potential in order to create value and competitive advantages for organizations (Subhani et al., 2024; Neuhofer, Buhalis, & Ladkin, 2015). According to research by Umar, Khan, Zia-ul-haq, Yusliza, and Farooq (2022), digital transformation has a favorable effect on human resource management functions. However, the "green" component is not taken into consideration. By confirming the positive impact of digital transformation on sustainable performance, our research closes this gap. By offering collaborative platforms, transparent supply chains, intelligent data analytics, and strong data analytics, digital transformation makes it possible to deploy GSCM.

Businesses now need to give ecological sustainability a priority due to the growing environmental degradation. Determining the impact of sustainability on business innovation has become crucial in this setting (Colovic, 2022; Almada et al., 2025). It is important to recognize that green initiatives are becoming more widely adopted worldwide, which encourages businesses to improve their socio-environmental performance via creative methods. The finding that companies' green procedures lessen environmental pollution has enhanced the sustainable performance of GI processes in recent years (Verhoef et al., 2021; Akram et al., 2024). In a similar vein, businesses' GI policies play a critical role in accomplishing their goals, including managing green supply chains. By guiding their structure operations, effective GI strategies lessen the environmental impact of businesses (Vial, 2019; Watto et al., 2019). Organizations' long-term performance has improved as a result of the increased attention given to the adoption of environmentally friendly practices. The adoption of green solutions has made it easier for new businesses to expand, which has improved their supply chain management and operational sustainability.

Additionally, this study has confirmed the intermediate role of green supply chain management (GSCM) in relation to digital transformation, the green innovation strategy, and the triple bottom line of sustainable performance. From a resource-based viewpoint, the Green innovation approach has the ability to turn workers into unique and valuable assets, contributing to the material and immaterial assets and capacities of businesses. The company will gain a long-lasting competitive edge as a result. The results of (Ni & Liu, 2021; Watto et al., 2020) support this claim. Green supply chain management actively supports company sustainable development by integrating sustainable development ideas throughout different supply chain components. Fostering social responsibility, improving resource efficiency, and lessening environmental impact are ways to do this.

Conclusions, Limitations, and Future Research

This study examines the synergistic effects of green supply chain management (GSCM) on the performance of sustainable firms in the context of the increasing demand for businesses to reconcile sustainable development and digital transformation. The model is assessed using PLS-SEM, with data obtained from a questionnaire survey that was distributed to manufacturing companies in Pakistan. A total of 411 responses were obtained. The implications of this study are substantial for both policymakers and administrators of automotive manufacturing companies.

They can be employed as a basis for the development of more effective strategies and policies that will enhance the capabilities of companies to develop innovations that could mitigate environmental risks and other negative consequences of climate change. The current study contributes to the body of knowledge on innovation and sustainability by analyzing and contemplating the mediating role of green supply chain management (GSCM) in the relationship between green innovation and firm performance. In addition, it contributes to the advancement of new knowledge concerning the mediating impact of GSCM practices on the relationship between green innovation strategy and digital transformation on Sustainable performance, particularly in the context of a developing economy. However, it is imperative to acknowledge a number of limitations in the study design. At the outset, the research findings are contingent upon a sample size that is relatively small and is exclusively sourced from a single country. Subsequent investigations should strive to encompass a broader spectrum of industry enterprises, encompassing both domestic and global sectors. This will enhance the generalizability and robustness of the findings.

Secondly, the data collected in this article are self-reported corporate behavior by the participants, and the use of a singular evaluation method can lead to specific deviations from the norm.

Future research may employ a combination of self-evaluation and objective data. Additionally, the data collection for this article was conducted simultaneously. The inadequacy of cross-sectional datasets renders it impossible to evaluate the intricate causal relationships between variables and the hysteresis of impacts. The utilization of longitudinal datasets should be pursued in forthcoming research. The scope of this article has the potential to be expanded through subsequent research, which could use the obtained findings as a foundation for the development of more intricate and comprehensive models. For instance, it is feasible to conduct a more thorough evaluation of digital transformation and to examine additional green management practices that have been identified in the existing literature.

References

1. Afum, E., Zhang, R., Agyabeng-Mensah, Y., & Sun, Z. (2021). Sustainability excellence: The interactions of lean production, internal green practices and green product innovation. *International Journal of Lean Six Sigma*, 12(6), 1089–1114. <https://doi.org/10.1108/IJLSS-07-2020-0109>
2. AiY.-H., Peng, D.-Y., & Xiong, H.-H. (2021). Impact of environmental regulation intensity on green technology innovation: From the perspective of political and business connections. *Sustainability*, 13(9), 4862. <https://doi.org/10.3390/su13094862>
3. Ameer, F., & Khan, N. R. (2022). Green entrepreneurial orientation and corporate environmental performance: A systematic literature review. *European Management Journal*, 1–4. <https://doi.org/10.1016/j.emj.2022.04.003>
4. Asadi, S., OmSalameh Pourhashemi, S., Nilashi, M., Abdullah, R., Samad, S., Yadegaridehkordi, E., Aljojo, N., & Razali, N. S. (2020). Investigating influence of green innovation on sustainability performance: A case on Malaysian hotel industry. *Journal of Cleaner Production*, 258, 120860. <https://doi.org/10.1016/j.jclepro.2020.120860>
5. Awan, U., Arnold, M. G., & Golgeci, I. (2021). Enhancing green product and process innovation: Towards an integrative framework of knowledge acquisition and environmental investment. *Business Strategy and the Environment*, 30(2), 1283–1295. <https://doi.org/10.1002/bse.2684>

6. Proksch, D., Rosin, A. F., Stubner, S., & Pinkwart, A. (2024). The influence of a digital strategy on the digitalization of new ventures: The mediating effect of digital capabilities and a digital culture. *Journal of small business management*, 62(1), 1-29.
7. Baah, C., Jin, Z., & Tang, L. (2020). Organizational and regulatory stakeholder pressures friends or foes to green logistics practices and financial performance: Investigating corporate reputation as a missing link. *Journal of Cleaner Production*, 247, 119125. <https://doi.org/10.1016/j.jclepro.2019.119125>
8. Gelhard, C., & Von Delft, S. (2016). The role of organizational capabilities in achieving superior sustainability performance. *Journal of Business Research*, 69(10), 4632–4642. <https://doi.org/10.1016/j.jbusres.2016.03.053>
9. Subhani, I. U. H., Fan, J., Asdullah, M. A., Watto, W. A., & Nigar, F. (2024). The relationship between dimensions of corporate social responsibility and consumer's buying intentions in a cross-cultural context. *Future Business Journal*, 10(1), 129.
10. Kouser, R., Mahmood, G., Watto, W. A., Fahlevi, M., & Aziz, A. L. (2025). Assessing the impact of green manufacturing and green technology innovation on sustainable green practices: unveiling the mediating role of eco-design. *International Journal of Sustainable Engineering*, 18(1), 2538868.
11. Akram, H., Li, J., Irfan, M., & Watto, W. A. (2025). Analyzing environmental concerns of sustainable development goals in SAARC region: how carbon emissions policy influence environmental sustainability?. *International Journal of Environmental Science and Technology*, 22(7), 5911-5928.
12. Watto, W. A., Abubakar, M., Kouser, R., Quddus, A., & Fayaz, M. (2025). Green supply chain management practices and sustainable firm performance via green dynamic capacity and green entrepreneurial orientation (GEO) mediation of green innovation. *International Journal of Innovation Science*.
13. Akram, H., Li, J., Asdullah, M. A., Shabbir, M. S., Watto, W. A., & Rasheed, T. (2025). Interlinkages Between Financial Markets and Minerals (1990–2023): Implications for Global Energy Transitions and Environmental Sustainability. *Sustainable Development*.
14. Asdullah, M. A., Watto, W. A., Ijaz, A., & Zeshan, M. (2025). Banking for a greener future: a systematic review of sustainable initiatives in South Asia. *Journal of Banking Regulation*, 1-17.
15. Watto, W. A. (2024). From lifestyle to creative economy: Consumer choices, services capes, and digital drivers in Pakistan's coffee market. *Central Community Development Journal*, 4(1), 21-28.
16. Kamble, S., Gunasekaran, A., & Dhone, N. C. (2020). Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian manufacturing companies. *International Journal of Production Research*, 58(5), 1319–1337.
17. 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.
18. Yusliza, M. Y., Amirudin, A., Rahadi, R. A., Nik Sarah Athirah, N. A., Ramayah, T., Muhammad, Z., Dal Mas, F., Massaro, M., Saputra, J., & Mokhlis, S. (2020). An investigation of pro-environmental behaviour and sustainable development in Malaysia. *Sustainability*, 12(17), 7083. <https://doi.org/10.3390/su12177083>
19. Zhou, Y., Shu, C., Jiang, W., & Gao, S. (2019). Green management, firm innovations, and environmental turbulence. *Business Strategy and the Environment*, 28(4), 567–581. <https://doi.org/10.1002/bse.2265>

20. Sun, H., Mohsin, M., Alharthi, M., & Abbas, Q. (2020). Measuring environmental sustainability performance of South Asia. *Journal of Cleaner Production*, 251, 119519. <https://doi.org/10.1016/j.jclepro.2019.119519>
21. Su, X., Xu, A., Lin, W., Chen, Y., Liu, S., & Xu, W. (2020). Environmental leadership, green innovation practices, environmental knowledge learning, and firm performance. *SAGE Open*, 10(2), 215824402092290. <https://doi.org/10.1177/2158244020922909>
22. Musaad O, A. S., Zhuo, Z., Musaad O, A. O., Ali Siyal, Z., Hashmi, H., & Shah, S. A. A. (2020). A fuzzy multi-criteria analysis of barriers and policy strategies for small and medium enterprises to adopt green innovation. *Symmetry*, 12(1), 116. <https://doi.org/10.3390/sym12010116>
23. Singh, S. K., Giudice, M. D., Chierici, R., & Graziano, D. (2020). Green innovation and environmental performance: The role of green transformational leadership and green human resource management. *Technological Forecasting and Social Change*, 150, 119762. <https://doi.org/10.1016/j.techfore.2019.119762>
24. Zhang, L., Zhao, S., Cui, L., & Wu, L. (2020). Exploring green innovation practices: Content analysis of the fortune global 500 companies. *SAGE Open*, 10(1), 215824402091464. <https://doi.org/10.1177/2158244020914640>
25. Kamble, S. S., Gunasekaran, A., & Sharma, R. (2018). Analysis of the driving and dependence power of barriers to adopt industry 4.0 in Indian manufacturing industry. *Computers in Industry*, 101, 107–119.
26. Sharma, R., Jabbour, C. J. C., & Lopes de Sousa Jabbour, A. B. (2021). Sustainable manufacturing and industry 4.0: What we know and what we don't. *Journal of Enterprise Information Management*, 34(1), 230–266.
27. Neuhofer, B., Buhalis, D., & Ladkin, A. (2015). Smart technologies for personalized experiences: A case study in the hospitality domain. *Electronic Markets*, 25, 243–254.
28. Dubey, R., Gunasekaran, A., Childe, S. J., Papadopoulos, T., Luo, Z., Wamba, S. F., et al. (2019). Can big data and predictive analytics improve social and environmental sustainability? *Technological Forecasting and Social Change*, 144, 534–545.
29. Lopes de Sousa Jabbour, A. B., Jabbour, C. J. C., GodinhoFilho, M., & Roubaud, D. (2018). Industry 4.0 and the circular economy: A proposed research agenda and original roadmap for sustainable operations. *Annals of Operations Research*, 270, 273–286.
30. Sarkis, J. (2012). A boundaries and flows perspective of green supply chain management. *Supply Chain Management: An International Journal*, 17(2), 202–216.
31. Khan, I. S., Ahmad, M. O., & Majava, J. (2021). Industry 4.0 and sustainable development: A systematic mapping of triple bottom line, circular economy and sustainable business models perspectives. *Journal of Cleaner Production*, 297, Article 126655.
32. Khan, M. T., Idrees, M. D., & Haider, Y. (2023). Industry 4.0 impacts on operational and green innovation performances with the mediation of green practices. *International Journal of Productivity and Performance Management*.
33. Beier, G., Niehoff, S., Ziems, T., & Xue, B. (2017). Sustainability aspects of a digitalized industry—A comparative study from China and Germany. *International journal of precision engineering and manufacturing-green technology*, 4, 227–234.
34. YildizÇankaya, S., & Sezen, B. (2019). Effects of green supply chain management practices on sustainability performance. *Journal of Manufacturing Technology Management*, 30(1), 98–121.
35. Rajeev, A., Pati, R. K., Padhi, S. S., & Govindan, K. (2017). Evolution of sustainability in supply chain management: A literature review. *Journal of Cleaner Production*, 162, 299–314.

36. Rehman Khan, S. A., & Yu, Z. (2021). Assessing the eco-environmental performance: An PLS-SEM approach with practice-based view. *International Journal of Logistics Research and Applications*, 24(3), 303–321.
37. Ringle, C. M. (2005). SmartPLS 2.0 (M3). [http://www. smartpls. de](http://www.smartpls.de).
38. Sellbom, M., &Tellegen, A. (2019). Factor analysis in psychological assessment research: Common pitfalls and recommendations. *Psychological assessment*, 31(12), 1428.
39. Cheah, J.-H., Roldán, J. L., Ciavolino, E., Ting, H., &Ramayah, T. (2021). Sampling weight adjustments in partial least squares structural equation modeling: guidelines and illustrations. *Total Quality Management & Business Excellence*, 32(13-14), 1594-1613.
40. Sellbom, M., &Tellegen, A. (2019). Factor analysis in psychological assessment research: Common pitfalls and recommendations. *Psychological assessment*, 31(12), 1428.
41. Xie, Y., & Breen, L. (2012). Greening community pharmaceutical supply chain in UK: A cross boundary approach. *Supply Chain Management: An International Journal*, 17(1), 40–53.
42. Umar, M., Khan, S. A. R., YusoffYusliza, M., Ali, S., & Yu, Z. (2022). Industry 4.0 and green supply chain practices: An empirical study. *International Journal of Productivity and Performance Management*, 71(3), 814–832.
43. Umar, M., Khan, S. A. R., Zia-ul-haq, H. M., Yusliza, M. Y., & Farooq, K. (2022). The role of emerging technologies in implementing green practices to achieve sustainable operations. *The TQM Journal*, 34(2), 232–249.
44. Li, Y., Dai, J., & Cui, L. (2020). The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model. *International Journal of Production Economics*, 229, Article 107777.
45. Li, H., Wu, Y., Cao, D., & Wang, Y. (2021). Organizational mindfulness towards digital transformation as a prerequisite of information processing capability to achieve market agility. *Journal of Business Research*, 122, 700–712.
46. Li, Q., Yu, P., & Wu, X. (2016). Managing perishable inventories in retailing: Replenishment, clearance sales, and segregation. *Operations Research*, 64(6), 1270–1284.
47. Gong, C., Ribiere, V., 2021. Developing a unified definition of digital transformation. *Technovation* 102, 102217.
48. Pagani, M., 2013. Digital business strategy and value creation: framing the dynamic cycle of control points. *MIS Q.* 37 (2), 617–632.
49. Li, L., Su, F., Zhang, W., Mao, J.-Y., 2017. Digital transformation by SME entrepreneurs: a capability perspective. *Inf. Syst. J.* 28 (6), 1129–1157
50. Goerzig, D., Bauernhansl, T., 2018. Enterprise architectures for the digital transformation in small and medium-sized enterprises. *Procedia CIRP* 67, 540–545.
51. Nasiri, M., Ukko, J., Saunila, M., Rantala, T., 2020. Managing the digital supply chain: the role of smart technologies. *Technovation* 96–97, 102121.
52. Frank, A.G., Mendes, G.H., Ayala, N.F., Ghezzi, A., 2019. Servitization and Industry 4.0 convergence in the digital transformation of product firms: a business model innovation perspective. *Technological Forecasting and Social* 141, 341–35
53. Ceipek, R., Hautz, J., Petruzzelli, A.M., De Massis, A., Matzler, K., 2021. A motivation and ability perspective on engagement in emerging digital technologies: the case of Internet of Things solutions. *Long. Range Plan.* 54 (5).
55. Hair, J., Andreson, R., Tatham, R., & Black, W. (1998). *Multivariate data analysis*. 5th (ed) Prentice-Hall Inc. *Unites States of America*.
56. Hair, J. F., Ringle, C. M., &Sarstedt, M. (2012). Partial least squares: the better approach to structural equation modeling? *Long range planning*, 45(5-6), 312-319.

57. Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial least squares structural equation modeling: Rigorous applications, better results and higher acceptance. *Long range planning*, 46(1-2), 1-12.
58. Colovic, A., 2022. Leadership and business model innovation in late internationalizing SMEs. *Long. Range Plan.* 55 (1), 102083.
59. Urbinati, A., Bogers, M., Chiesa, V., Frattini, F., 2019. Creating and capturing value from Big Data: a multiple-case study analysis of provider companies. *Technovation* 84–85, 21–36.
60. Schallmo, D., Williams, C.A., Boardman, L., 2017. Digital transformation of business models - best practice, enablers, and roadmap -. *Int. J. Innovat. Manag.* 21 (8), 1740014.
61. Vial, G., 2019. Understanding digital transformation: a review and a research agenda. *J. Strat. Inf. Syst.* 28, 118–144
62. Warner, K.S., Wager, M., 2019. Building dynamic capabilities for digital transformation: an ongoing process of strategic renewal. *Long. Range Plan.* 52 (3), 326–349.
63. Karimi, J., Walter, Z., 2015. The role of dynamic capabilities in responding to digital disruption: a factor-based study of the newspaper industry. *J. Manag. Inf. Syst.* 32 , 39–81.
64. Wu, F., Hu, H., & Lin, H. (2021). Enterprise digital transformation and capital market performance: Empirical evidence from stock liquidity. *Management World*, 37(07). <https://doi.org/10.19744/j.cnki.11-1235/f.2021.0097>
65. Li, X., Dang, L., & Zhao, C. (2022). Digital transformation, integration into global innovation networks and innovation performance. *China Industrial Economics*, 10, 43–61. <https://doi.org/10.19581/j.cnki.ciejournal.2022.10.003>
66. Ding, X. A., Sheng, Z. L., Appolloni, A., Shahzad, M., & Han, S. J. (2024). Digital transformation, ESG practice, and total factor productivity. *Business Strategy and the Environment*, 15. <https://doi.org/10.1002/bse.3718>
67. Fernández-Portillo, A., Almodovar-González, M., Sanchez-Escobedo, M. C., & CocaPérez, J. L. (2022). The role of innovation in the relationship between digitalisation and economic and financial performance. A company-level research. *European Research on Management and Business Economics*, 28(3), 10. <https://doi.org/10.1016/j.iedeen.2021.100190>. Article 100190.
68. Zhao, C., Wang, W., & Li, X. (2021). How does digital transformation affect total factor productivity. *Economics of Finance and Trade*, 42(07), 114–129. <https://doi.org/10.19795/j.cnki.cn11-1166/f.20210705.001>
69. Jin, Y., Wen, W., & He, Y. (2022). The effect of digital transformation on enterprise green innovation: Based on empirical evidence from listed manufacturing companies in China. *Finance and Trade Research*, 33(07), 69–83. <https://doi.org/10.19337/j.cnki.34-1093/f.2022.07.006>
70. Chen, N., Sun, D., & Chen, J. (2022b). Digital transformation, labour share, and industrial heterogeneity. *Journal of Innovation & Knowledge*, 7(2), Article 100173. <https://doi.org/10.1016/j.jik.2022.100173>
71. Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *Journal of Strategic Information Systems*, 28(2), 118–144. <https://doi.org/10.1016/j.jsis.2019.01.003>
72. Ni, K., & Liu, X. (2021). Digital transformation and enterprise growth: Theoretical logic and Chinese practice. *Economic Management*, 43(12), 79–97. <https://doi.org/10.19616/j.cnki.bmj.2021.12.005>
73. Caputo, A., Pizzi, S., Pellegrini, M. M., & Dabic, M. (2021). Digitalization and business models: Where are we going? A science map of the field. *Journal of Business Research*, 123, 489–501. <https://doi.org/10.1016/j.jbusres.2020.09.053>

74. Qi, L., & Xiao, X. (2020). Enterprise management reform in the era of digital economy. *Management World*, 36(06). <https://doi.org/10.19744/j.cnki.11-1235/f.2020.0091>, 135–152+250
75. Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., et al. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889–901. <https://doi.org/10.1016/j.jbusres.2019.09.022>
76. Almada, A., Abbas, U., Ahmad Watto, W., Asdullah, M. A., Fahlevi, M., & Amrullchdan, D. (2025). The Islamic effect: Exploring the dynamics of Islamic events on sustainable performance of Islamic and conventional stock markets. *Uncertain Supply Chain Management*, 12, 235-248.
77. Watto, W. A., & Monium, A. (2020). The impact of ethical context on employees in-role performance and citizenship behavior in telecom sector of pakistan: the mediating role of perceived organizational support. *International Journal of Environmental, Sustainability, and Social Science*, 1(1), 25-35.
78. Akram, H., Li, J., & Watto, W. A. (2024). The impact of urbanization, energy consumption, industrialization on carbon emissions in SAARC countries: a policy recommendations to achieve sustainable development goals. *Environment, Development and Sustainability*, 1-32.
79. Watto, W. A., Khan, Z., Monium, A., & Abubakar, M. (2019). How Do Ethical Leadership and Organizational Justice Affect Work Outcomes? Does Perceived Organizational Support Mediate the Relationships?. *Business Perspective Review*, 1(1), 53-70.