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ARTIFICIAL INTELLIGENCE ADOPTION AND GREEN SUPPLY CHAIN MANAGEMENT IN SMES: THE ROLE OF ORGANIZATIONAL CAPABILITIES AND TOP MANAGEMENT SUPPORT

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ABSTRACT

Purpose: *This research study aims at critically analyzing the factors that guide the implementation and adoption of Green Supply Chain Management (GSCM) among small and medium size enterprises (SMEs) in the Pakistani context. It seeks to shed light on the key functions of artificial intelligence (AI) adoption, internal organizational support and executive approval in promoting sustainable operations within supply chains. The research also hopes to provide practical information and empirically based findings to both managerial professionals and policy makers to enhance the development of environmentally friendly SMEs with the capacity to compete competitively.*

Design: *The empirical study was performed using Partial Least Squares-Structural Equation Modelling (PLS-SEM) with a carefully designed survey instrument, which guaranteed a solid collection of data and an accurate analysis.*

Findings: *The discussion demonstrated that AI adoption has a positive impact on GSCM in SMEs with most of its effects triggering the creation of internal green capabilities like innovation, operational practices, and organizational culture. These abilities came out as the key mediators highlighting that no one can achieve desirable sustainable supply-chain results without the use of technology. Executive endorsement (TMS) magnified the effects of the specific green capabilities, particularly the cultural evolution and innovation, on GSCM, and thus the necessity of leadership in guiding the sustainability efforts. Taken together, the findings indicate that successful GSCM is conditional on the interaction-based impacts of technological adoption, organizational ability building, and managerial commitment, and provides a strategic roadmap on how SMEs can operationalize sustainable practices effectively.*

Theoretical Contribution: *The study highlights the importance of introducing AI and developing internal green capabilities as the major sources of GSCM in SMEs. It shows that the synergies between technology, innovation, operations improvement, and cultural alignment strengthen sustainable supply-chain results. In addition, the effectiveness of these capabilities is further reinforced by executive leadership and hence explains why sustainability goals are critically dependent on management.*

Practical Implications: *The findings indicate to SME leaders that they need to invest in AI technologies and foster in-house green capabilities to promote sustainable performance in the supply chain. These capabilities are important to be converted into practice with the help of strong leadership support. Policymakers have been encouraged to support this change by providing training*

programs and financial incentives as well as strategic direction that would allow SME to adopt technological innovations with sustainable business paradigms.
Keywords: *AI adoption, Green Supply Chain Management, Green Innovation Capability, Green Operational Practices, Green Organizational Culture, Top Management Support, SME*

1.INTRODUCTION

Over the past few years, sustainability has increasingly become an important priority to organizations across the globe, especially in the sphere of supply chain management (Brandao & Godinho-Filho, 2022). Companies are under increasing pressure from stakeholders, regulatory authorities, and customers who like to implement environmentally responsible policies, which would reduce the effects on the environment, yet maintain operational efficiency at the same time (Latip et al., 2022). Green Supply Chain Management (GSCM) is in this respect one of the main tools that allow firms to incorporate sustainability into operatioal and strategic practices. GSCM is the practice of environmentally friendly procurement, production, logistics, and waste-management with the twin aim of improving environmental performance and the overall performance of the organization (Habib et al., 2021). Although gaining prominence, most small and medium-sized enterprises (SMEs) still face the challenge of an inability to successfully enact GSCM practices due to resource limitations, lack of technological capacity as well as managerial assistance (Okeke, 2024).

Recent advancements in Artificial Intelligence (AI) is an excellent way out of these issues to the extent that it will enable organizations with the tools to automate things, improve decision-making, and develop innovation in green operations (Kulkov et al., 2024). The implementation of AI has the prospect of enhancing the ability of green innovation, green operational and green organizational culture, which works to provide the internal processes needed to make green supply-chain management effective (Abdulmuhsin et al., 2025). Nevertheless, technology alone cannot do the job; on a deeper level, the effectiveness of AI in promoting sustainable practices relies significantly upon the organizational resources and the commitment of leadership to them (Kulkov et al., 2024). Top Management Support plays a pre-eminent role in ensuring the mobilization of green capabilities to ensure the achievement of the desired supply-chain sustainability results, as per the postulates of the Upper Echelons Theory (Bhutto & Shaikh, 2025).

Although the growing awareness of the connection between AI, green capabilities, and green supply-chain management presents the opportunity to empirically investigate the processes that would enable AI adoption to cause sustainable levels of supply-chain performance, limited empirical research has been conducted to date, and it is essential to focus specifically on the SME (Rashid et al., 2025). The study aims to address this gap by examining how the adoption of AI can affect green supply-chain management through green innovation capability, green operational practices, and green organizational culture, and at the same time to also discuss how the moderating variable of Top Management Support can have an impact. Combining the expertise of the Resource-Based View (RBV) and Upper Echelons Theory, the study provides a multifaceted framework that can be used to explain both organizational and technological antecedents of green supply-chain management. The results, therefore, supplement theoretical discussion and provide practical implications that present SMEs with the roadmap of integrating AI and endogenous capabilities to enhance supply-chain sustainability.

2. Literature Review

2.1 Theoretical Framework

The Resource-Based View (RBV) was initially developed by Barney et al. (2001) and argues that companies gain sustainable competitive advantage when they utilize resources which are valuable, rare, inimitable, and non-substitutable (VRIN). Under the umbrella of this query, the implementation of artificial intelligence (AI) is viewed as a strategic technological resource that could push the organizational performance to new levels, should it be utilized in the right way (Olan et al., 2022). The internal capabilities that can help firms to apply AI-based insights to create environmentally sustainable supply-chain practices include green organizational culture, green innovation capability and green operational practices (Bag et al., 2021). In line with this, RBV also argues that technology is not enough, but it should be combined with organizational capabilities to produce high-quality green supply-chain management (GSCM) (Rusmawati & Soewarno, 2021).

According to Hambrick and Mason (1984), the Upper Echelons Theory (UET) suggests that the impact of the high-level executive attributes of values, experiences as well as support has a significant influence on organizational performance. Top-management support is thus critical in making sure that AI implementation and green capabilities are converted into viable GSCM practices (Gallo et al., 2023). Through the addition of UET, the study anticipates the contingency impact of leadership and unravels that the same organizational abilities can foster different results, depending on the executive support and intervention (McCants, 2024).

Together, RBV and UET are a strong theoretical framework in this study. RBV describes the processes through which AI adoption enhances green capabilities and supply-chain sustainability Kumar et al. (2024), and UET outlines the conditions of the boundary that differentiate the most effective efficacy of the mechanisms (Neely Jr et al., 2020). Such combination of these two points of view provides the study with an in-depth frame to examine the direct, mediating, and moderating relationships hypothesized in the model, and thus ensure the theoretical rigor and practical natureto organizations that seek to exploit AI in the aim of achieving sustainable supply-chain management.

2.2 Hypothesis Development

2.2.1 AI Adoption, Green organizational culture, Green innovation capability, and Green Supply Chain Management.

The use of artificial intelligence (AI) has been seen as a disruptive force of sustainability in organizations (Schwaeke et al., 2025). AI is a tool that makes real-time data analytics, predictive modeling, and automation, which can improve the making of environmental decisions and operational efficiency (Zong & Guan, 2025). Within a green organizational culture framework, AI aids the creation of eco-friendly habits and decision-making systems and facilitates the principles of sustainability throughout the enterprise (Arise & Muzuva, 2024).

In terms of the capability of green innovation, AI allows creating environmentally friendly solutions through insights into the optimization of resources, the redesigning of products, and the minimization of waste (Lodhi et al., 2024). Similarly, AI can be used to improve green operational practices by enhancing process efficiency and energy management as well as supply-chain visibility, eventually resulting in a smaller environmental footprint (Huang & Mao, 2024). All these capabilities form a basis of improved Green Supply Chain Management (GSCM), whereby AI implementation will guarantee a more sustainable procurement, production, and logistics cycle (Nahr et al., 2021).

The existing literature highlights that the use of AI is a direct contributor of the above green outcomes, but most studies focus on technical or operational efficiencies, instead of the organizational change that is needed to turn AI into sustainable supply-chain practices (Malhotra & Manzoor, 2025).

H1: *AI adoption has a direct positive relationship with Green organizational culture*

H2: *AI adoption has a direct positive relationship with Green innovation capability*

H3: *AI adoption has a direct positive relationship with Green operational practices*

H4: *AI adoption has a direct positive relationship with Green Supply chain management*

2.2.2 Green Capabilities and Green Supply Chain Management (H5–H7)

The concept of green organizational capabilities is a primary hypothesis in the Green Supply Chain Management (GSCM) context because the organizational capabilities play the key role of offering the internal structures, knowledge base, and routines that are necessary to support the process of sustainable operations (Habib & Bao, 2019). Empirical evidence of the direct influence of green organizational culture, which can be defined as a set of environmental values, normative commitments, and employees who are committed to sustainability, has been found to have a direct impact upon the implementation of environmentally friendly supply chain practices (Hair et al., 2023). It has been proved that companies that declare a strong green spirit have a much higher probability of carrying out responsible procurement, production, and distribution procedures, consequently attaining better GSCM results (de Sousa Jabbour et al., 2015).

Equally, a green innovation capability can be used to develop sustainable processes and products, which can also enable companies to minimize the environmental impacts and increase their levels of operation effectiveness (Dangelico et al., 2017). Available sources show that organizations with high green innovation competencies are in a better position to design and implement environmentally friendly solutions across the chain of supply and thus successfully enhance the performance of GSCM (Le et al., 2022). This approval also suggests that the environmental factor is incorporated in product development as opposed to being added as an afterthought; it is through this incorporation that sustainability becomes part of process enhancement, which builds a stronger model of supply chain.

The actionable aspect of green capabilities is a set of green operational practices that include sustainable procurement, energy-efficient production, and logistics that are environmentally conscious (Lăzăroiu et al., 2020). The results of empirical studies indicate that the systematically implemented green operational practices result in increased levels of supply-chain sustainability because the initiatives transform strategic sustainability goals into the operational results (Famiyeh et al., 2018). Together, a green organizational culture, innovation prowess, and operational rigor provide the internal mechanisms that are required in organizations to achieve successful GSCM.

H5: *Green Organizational Culture has a significant positive effect on Green Supply Chain Management.* ***H6:*** *Green Innovation Capability has a significant positive effect on Green Supply Chain Management.* ***H7:*** *Green Operational Practices have a significant positive effect on Green Supply Chain Management.*

2.2.3 Mediating Role of Green Capabilities

Although the merger with AI does bring forth significant technological advantages, its impact on the green supply chain management (GSCM) is largely indirect and goes through the organizational capabilities of the firm (Aljoghaiman & Mirzaliev, 2024). The results of empirical studies indicate that green organizational culture is an active mediator of technology-based sustainability efforts that incorporate ecological principles into everyday activities and determine the behavior of employees (Jabbour et al., 2019). Similarly, green innovation capability serves as a translation system, in which AI-produced knowledge is turned into eco-innovation, and, in this way, environmental performance is improved (Zhu et al., 2020).

Green operational practices like sustainable procurement, production, and distribution are operational mediators, and its implementation makes sure that AI adoption produces quantifiable improvements to the sustainability of supply-chains (Rashid et al., 2025). It is possible to say that these mediating pathways echo the Resource Based View (RBV) and Dynamic Capabilities Theory, meaning that technology is not sufficient in itself; it should be supplemented by organizational routines, knowledge, and innovation capabilities to achieve better results in GSCM.

Overall, the research hypothesizes that green capabilities are crucial channels connecting the adoption of AI and GSCM (Makhdoom et al., 2025). Though previous studies have isolated these mediators, there is lack of holistic models which incorporate them, hence the need to conduct extensive empirical research on them.

H8: *Green Organizational culture mediates the relationship between AI adoption and Green supply chain Management*

H9: *Green Innovation capability mediates the relationship between AI adoption and Green supply chain Management*

H10: *Green Operational Practices mediates the relationship between AI adoption and Green supply chain Management*

2.2.4 Moderating Role of Top Management Support (H8–H10)

The support of top-management, which is one of the pillars of the technological and sustainable initiatives implementation, is universally accepted as a determining factor (Garcia-Ortega et al., 2021). Top-level commitment influences resource allocation, strategic alignment and organizational motivation, consequently enhancing the effectiveness of green capabilities (Yusliza et al., 2019). In particular, the influence of the top-management support on the relationship between green organizational culture, innovation capability, and operational practices and their influences on GSCM is moderated (Gull et al., 2024).

A green organizational culture that is clearly supported at the level of leadership is more easily converted into practice and thus leads to the increase of the supply-chain performance (Wang & Manopimoke, 2023). Similarly, managerial support ensures that AI-led innovation and operating projects obtain the necessary resources and priority, to cement their role in the GSCM deliverables (Bhattarai, 2025).

The moderating effect of top-management support is explained in the context of the Upper-Echelons Theory as it predicts the involvement of executive decision-making and commitment into the organizational outcomes (Ma et al., 2022). Although this phenomenon has found significant acceptance, empirical studies that evaluate its moderating role on many green capabilities are limited thus identifying a salient research gap that the study will help to fill.

H11: *Top management support moderates the relationship between Green organizational culture and Green Supply chain management*

H12: *Top management support moderates the relationship between Green innovation capability and Green Supply chain management*

H13: *Top management support moderates the relationship between Green operational practices and Green Supply chain management*

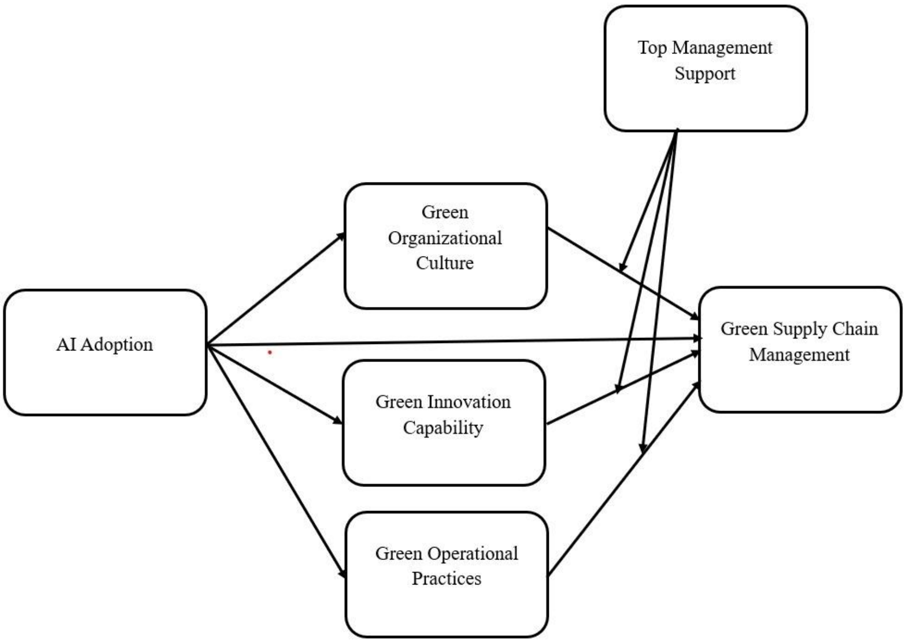

Figure 1: Conceptual Framework

Source: Author's own work

3. Methodology

3.1 Design and Data collection

This study focused on SME entrepreneurs in Pakistan, especially those involved in the business where AI implementation and green supply chain initiatives apply. All constructs, and AI adoption, green organizational culture, green innovation capability, green operational practices, GSCM, and top measured self administered questionnaire, which was adopted based on existing scales in previous studies. The questionnaire used a seven-point Likert scale, as recommended by (Hox & Boeije, 2005). To promote representativeness, a probability-based random sampling method was employed Mehmood et al. (2012) where 600 questionnaires were administered, and 500 responses were obtained, making it a response rate of 83.33%. Empirical analysis of 470 questionnaires was performed after eliminating 30 incomplete answers. To achieve credible results on the interrelationship between AI adoption, green capabilities, top management support and green supply chain management in Pakistani SME, statistical analyses were performed at a level of significance of 5 percent (0.05), which is two tailed.

3.2 Measures

The instruments used in the assessment of each construct under study in the current research were well established and reliable, thus validity and consistency were achieved. The answers of the participants were obtained on a seven-point Likert scale. The scale used to measure AI adoption entailed a ten-item scale based on the latest revised version suggested by (Larasati et al., 2023). Green innovation capability construct has been operationalized using eight items which included, four items of Green Product Innovation Capability and four items of Green Process Innovation Capability, based on the study of (Borah et al., 2023). The items used to measure green organizational culture were six items based on Wang (2019) and the items used to measure green operational practices were eleven based on (Jabbour et al., 2016). The three items that were assessed using Roh et al. (2022) when gauging green supply chain management and five items that were gauged using (Lee et al., 2016) when measuring top-management support. These measures are collectively a strong structure of measuring perceptions of the respondents concerning all the important constructs of the research.

4. Empirical Findings

Ali et al. (2018) state that the PLS-SEM method is a powerful tool of analysis, which is explained by its ability to conduct parallel analysis of sophisticated models. Hair et al. (2011) note that the PLS-SEM is especially beneficial when the data requirements are very low, and normality is not strictly met. As suggested by the methodology used by Henseler et al. (2009), the research hypotheses in this study were tested through a two-step process in SmartPLS. In the first stage, confirmatory factor analysis was done to measure the measurement model, analyzing the convergent validity as well as the discriminant one. The second stage involved the analysis of the structural model using path analysis with mediation and moderation. This rigorous methodological design could help to make an exhaustive evaluation of the interplay between the variables of the study.

4.1 Measurement Model Assessment

All the constructs have high validity and reliability in the measurement model. Most of the items have a factor loading greater than the recommended 0.7 factor loading, which means that every item has adequately captured its construct, with just a few items (e.g., GIC7 = 0.677, GIC8 = 0.689) slightly lower than the cutoff but not significant when considering overall model reliability. The Alpha coefficient values are 0.842 to 0.926 and the Composite Reliability (CR) values are more than 0.8, indicating that the use of AI, green innovation capability, green organizational culture, green operational practices, green supply chain management, and top management support all have excellent internal consistency.

Convergent validity is also established since the Constructs have AVE of all constructs that exceed 0.5, with the range of between 0.603 and 0.688. Interaction terms of moderation (GICTMS, GOPTMS, GOC*TMS) are properly modeled in PLS-SEM, which makes the moderation analysis reliable to be carried out. Overall, these findings demonstrate that the measurement model is strong, dependable and effective, which offers a good basis on which further structural model testing can be conducted to verify direct, mediating and moderating relationships between the study variables.

Table 1: Convergent Validity

	Items	Factor Loadings	Alpha	CR	AVE
AI Adoption	AD1	0.778	0.926	0.938	0.603
	AD2	0.786			
	AD3	0.835			
	AD4	0.736			
	AD5	0.712			
	AD6	0.785			
	AD7	0.768			
	AD8	0.839			
	AD9	0.792			
	AD10	0.723			
Green Innovation Capability	GIC1	0.835	0.917	0.933	0.637
	GIC2	0.793			
	GIC3	0.855			
	GIC4	0.898			
	GIC5	0.813			
	GIC6	0.800			
	GIC7	0.677			
	GIC8	0.689			
Green Organizational Culture	GOC1	0.684	0.919	0.933	0.608
	GOC2	0.796			
	GOC3	0.798			
	GOC4	0.844			
	GOC5	0.815			
	GOC6	0.850			
	GOP1	0.835			
Green Operational Practices	GOP2	0.822	0.886	0.914	0.639
	GOP3	0.733			
	GOP4	0.821			
	GOP5	0.771			
	GOP6	0.749			
	GOP8	0.772			
	GOP10	0.752			
	GOP11	0.754			
Green Supply Chain Management	GSCM1	0.821	0.842	0.894	0.679
	GSCM2	0.854			
	GSCM3	0.846			
Top Management Support	TMS1	0.824	0.886	0.917	0.688
	TMS2	0.853			
	TMS3	0.839			
	TMS4	0.745			
	TMS5	0.881			
	GIC * TMS	1.215	1.000	1.000	1.000
	GOP * TMS	1.434	1.000	1.000	1.000
	GOC * TMS	1.357	1.000	1.000	1.000

Fornell-Larcker criterion is a measure of discriminant validity that compares the square root of the Average Variance Extracted (AVE) of each construct, or the diagonal elements to the inter-construct associations. In the table, the diagonal coefficients (e.g. AI Adoption = 0.776, GIC = 0.798, GSCM = 0.824, TMS = 0.829) are consistently larger than the specific off-diagonal cross-loadings, and therefore also reflect the fact that each construct has a larger share of variance in common with its indicators than with any other construct. Therefore, the criterion is a confirmation of satisfactory discriminant validity, which assumes that the constructs are conceptually different. In comparison, the Heterotrait-Monotrait (HTMT) ratio is a stricter test of discriminant validity, the usual value of which is deemed acceptable as less than 0.85 (or 0.90 in certain methodological settings). In most construct pairs within the table, the values of the HTMT are below the 0.85 value, which supports the appropriateness of discriminant validity in most of the constructs. There are certain moderator terms that have slightly higher ratios such as GOP*TMS versus GOC at 0.856, which is not new in moderation studies but still within acceptable parameters based on the theory. A combination of the Fornell-Larcker test and the HTMT test confirms that the measurement model is a strong isolator of the constructs and ought to be applied to future structural equation modelling.

Table 2: Discriminant Validity (Fornell-Larcker)

	AI adoption	GIC*TMS	GOC*TMS	GOP*TMS	GIC	GOP	GOC	GSCM	TMS
AI adoption	0.776								
GIC*TMS	-0.272	1.000							
GOC*TMS	-0.388	0.929	1.000						
GOP*TMS	-0.421	0.922	0.923	1.000					
GIC	0.732	-0.084	-0.221	-0.250	0.798				
GOP	0.822	-0.295	-0.426	-0.404	0.774	0.780			
GOC	0.840	-0.247	-0.373	-0.403	0.790	0.781	0.800		
GSCM	0.912	-0.283	-0.398	-0.423	0.694	0.778	0.856	0.824	
TMS	0.909	-0.313	-0.434	-0.453	0.694	0.793	0.873	0.990	0.829

Table 3: Discriminant Validity (HTMT Ratio)

	AI adoption	GIC*TMS	GOC*TMS	GOP*TMS	GIC	GOP	GOC	GSCM	TMS
AI adoption									
GIC*TMS	0.282								
GOC*TMS	0.402	0.729							
GOP*TMS	0.437	0.633	0.593						
GIC	0.792	0.122	0.232	0.260					
GOP	0.888	0.308	0.445	0.421	0.842				

GOC	0.714	0.247	0.381	0.414	0.874	0.856		
GSCM	0.733	0.312	0.436	0.462	0.785	0.883	0.756	
TMS	0.785	0.335	0.464	0.483	0.767	0.878	0.665	0.567

Figure 2: Measurement Model

Source: SmartPLS

4.2 Structural Model Assessment

The direct effects suggest that the process of artificial intelligence adoption has a strong and statistically significant positive impact on all the internal green capabilities. Green Innovation Capability (β=0.732 t=20.919, p=0.001), Green Operational Practices (β=0.822 t=29.561, p=0.001), and Green Organizational Culture (840 t=39.243, p=0.001) are significantly enhanced by the adoption of AI. The results highlight the critical value of AI-based technologies in reinforcing innovation, operational performance, and culture-oriented towards the environment in the small and medium-sized businesses. Furthermore, the adoption of AI has a positive and significant direct impact on Green Supply Chain Management (GSCM) (= -0.083, = 3.680, = -0.001); however, the direct impact of AI on GSCM is relatively smaller, but it still reveals that organizational capabilities play a role in the direct and indirect impact of AI on GSCM.

In terms of implications of green capabilities on GSCM, Green Innovation Capability (0.034, 2.460, 0.007) and Green Organizational Culture (0.062, 3.238, 0.001) are both associated with GSCM significantly, although Green Operational Practices (0.036, 2.402, 0.008) also has a significant influence. Moderation analysis indicates that, Top Management Support (TMS) only plays a significant role in strengthening the relations between green innovation capability and GSCM

(0.037 0.041) and between green organizational culture and GSCM (0.051 0.002); however, its moderating role on green operational practices is weak, indicating that leadership commitment is especially relevant in the transformation of innovation and cultural orientation into sustainable supply chain performance.

The mediation analysis also supports the fact that AI adoption and GSCM have the partial relationship that is mediated by Green Innovation Capability (β = 0.025, t = 2.447, p = 0.007), thus showing that AI adoption increases GSCM through the promotion of green capabilities that are innovation oriented. The R^2 values are quite high, as AI adoption explains a significant portion of the variance in GIC, GOP, GOC, and an unusually large percentage of variance in GSCM, thus showing the strength of the proposed framework.

Table 4: Path Analysis (Direct Effects)

Direct Effects	Beta	(STDEV)	T Statistics	P Values	LL	UL
AI adoption -> GIC	0.732	0.035	20.919	**0.000**	0.666	0.784
AI adoption -> GOP	0.822	0.028	29.561	**0.000**	0.770	0.862
AI adoption -> GOC	0.840	0.021	39.243	**0.000**	0.799	0.871
AI adoption -> GSCM	0.083	0.023	3.680	**0.000**	0.042	0.117
GIC*TMs-> GSCM	0.037	0.021	1.744	**0.041**	0.074	0.004
GOC*TMS -> GSCM	0.051	0.018	2.830	**0.002**	0.021	0.080
GOP*TMS-> GSCM	0.006	0.015	0.423	**0.036**	0.016	0.033
GIC -> GSCM	0.034	0.014	2.460	**0.007**	0.012	0.057
GOP -> GSCM	0.036	0.015	2.402	**0.008**	-0.060	-0.011
GOC -> GSCM	0.062	0.019	3.238	**0.001**	-0.093	-0.031

Table 5: R Square

R Square	
GIC	0.536
GOP	0.676
GOC	0.706
GSCM	0.984

Table 6: Path Analysis (Indirect Effects)

Indirect effects	Beta	(STDEV)	T Statistics	P Values	LL	UL
AI adoption -> GIC -> GSCM	0.025	0.010	2.447	**0.007**	0.009	0.042
AI adoption -> GOP-> GSCM	0.029	0.013	2.355	**0.009**	0.050	0.009
AI adoption -> GOC -> GSCM	0.052	0.016	3.216	**0.001**	0.079	0.026

Figure 3: Structural Model Assessment

Source: SmartPLS

4.3 Moderation Analysis

The moderation results highlight the dominant position of the top-management support (TMS) in the mediation of the translation of internal green resources into the green supply chain management (GSCM) initiatives. An analysis of interaction indicates that the degree of GSCM variability among various degrees of green innovation capability (GIC) and green organizational culture (GOC) is greatly dependent on the intensity of the TMS. The organizational climate is therefore a critical factor that is critical in exploiting these resources successfully. With respect to the nexus between GIC and GSCM shown in Fig 4, empirical data shows that with the high level of TMS, the firms have a consistent ability of achieving high GSCM performance despite their inherent innovation ability. This finding indicates that such strong managerial support could directly drive the process of green supply-chain practices adoption and institutionalization, even in the environments that are envisioned by rather low innovation potential. GIC has a positive yet weak association with GSCM at an average level of TMS, suggesting that innovation competence has a role in green performance where there is a supportive environment of mid-level managers. On the other hand, in case of low TMS, GSCM stays rather low even in case of incremental gains in GIC, i.e. innovation prowess is not enough to induce significant improvement of GSCM without powerful top-level support.

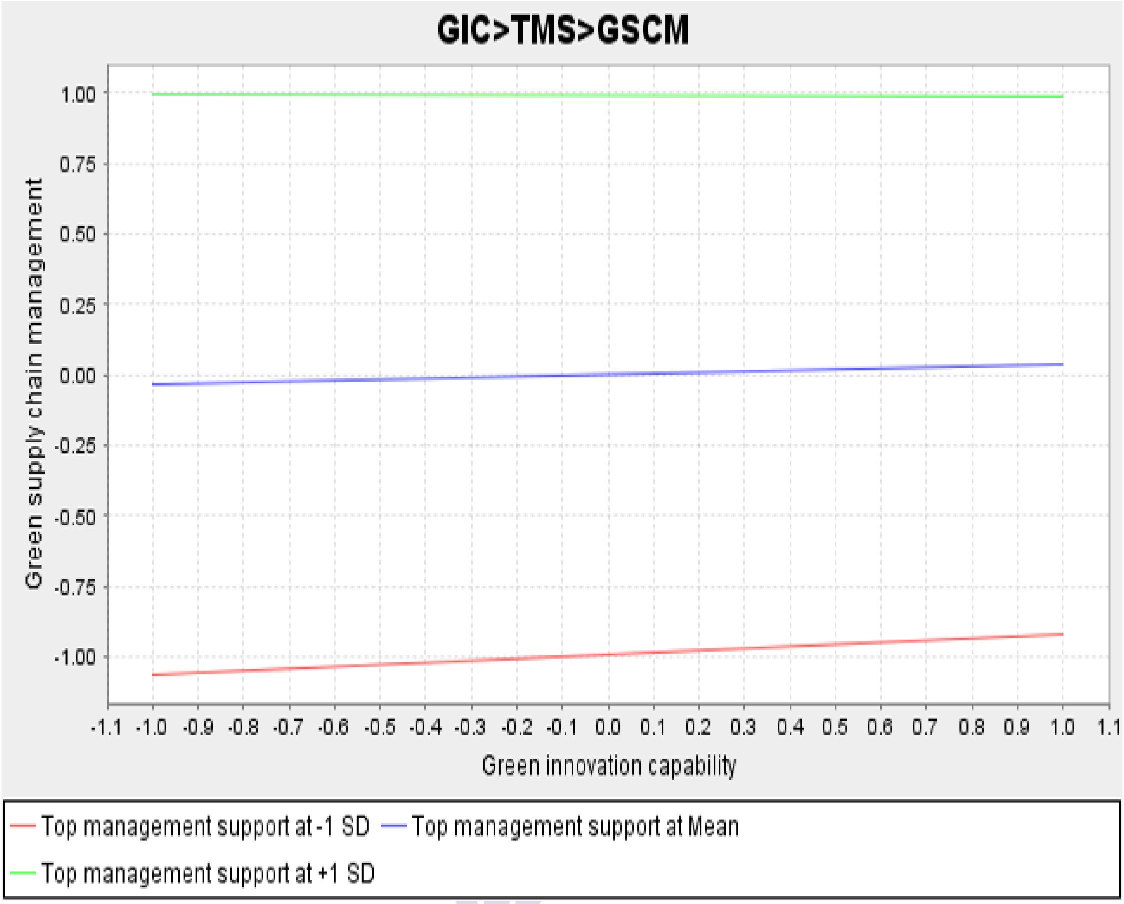

Figure 4: Moderation Effect 1

Source: SmartPLS

Regarding the nexus between the green organizational culture (GOC) of an organization and the green supply chain management (GSCM) shown in Figure 5, transformational managerial support (TMS) gains a significantly prominent moderating role. In the event of TMS being high, GSCM maintains a high steady level throughout all the levels of GOC, which suggests that a strong support of leaders would be able to institutionalize green supply-chain management practices despite the inherent energy of the organizational culture. In contrast, when the level of TMS is average, the relationship between GOC and GSCM becomes very slightly negative, thus showing that the values of green culture do not necessarily bring about efficient supply-chain operations, unless the managers guide managers to act as such. In the context where TMS is decreased, the GSCM reduction is even steeper in line with the higher levels of GOC, indicating that in the absence of the leader commitment, a green culture can be no more than an administrative symbol and a tool that does not yield a tangible outcome in terms of operations.

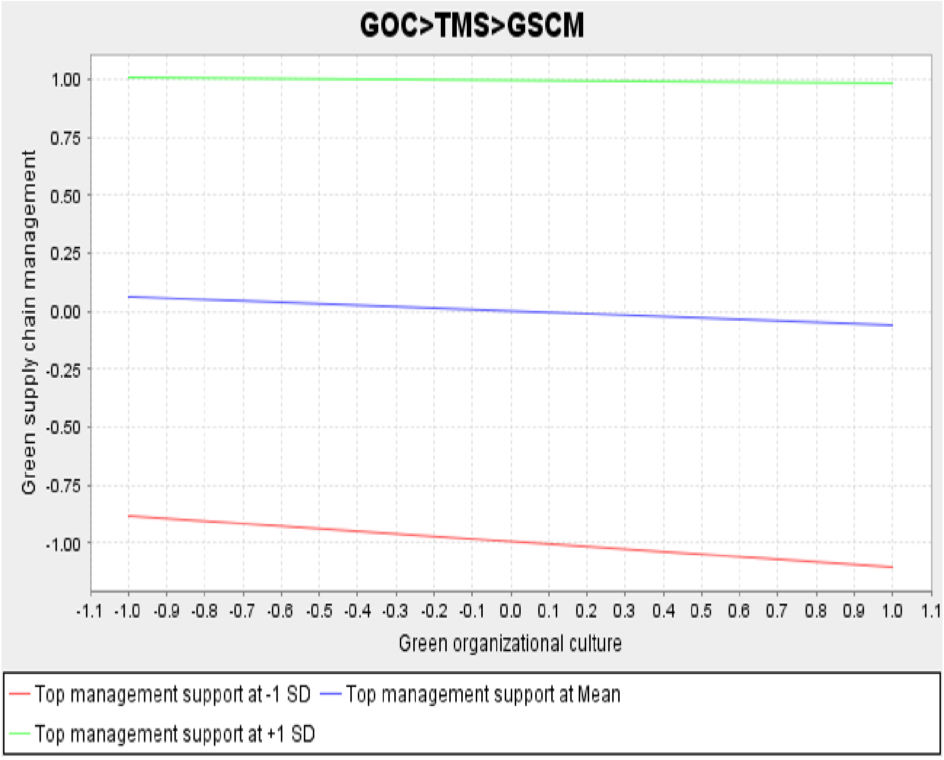

Figure 5: Moderation Effect 2
Source: SmartPLS

Figure 6 illustrates the conditional effects of Green Operational Practices (GOP) on Green Supply Chain Management (GSCM) at low (−1SD), mean and high (+ 1SD) Top Management Support (TMS). A very strong vertical distance between the three response curves testifies to a high main effect of TMS on GSCM; the entities enjoying high top-management support always demonstrate significantly high-quality green supply-chain performance, and the ones receiving reduced support record relatively poor results. On the other hand, gradients of all the three curves are small and shallow which means that GOP has a weak, slightly negative correlation with GSCM which remains constant and constant across all TMS strata. More importantly, the curves are nearly parallel, implying that TMS does not significantly alter the strength or the direction of the GOP GSCM relationship. Overall, although the top-management support has a conclusive, direct influence on the whole GSCM effectiveness, it does not have a significant moderating effect on the GOP. The empirical results thus support a strong primary effect of TMS as well as insignificant evidence of a significant GOP X TMS interaction.

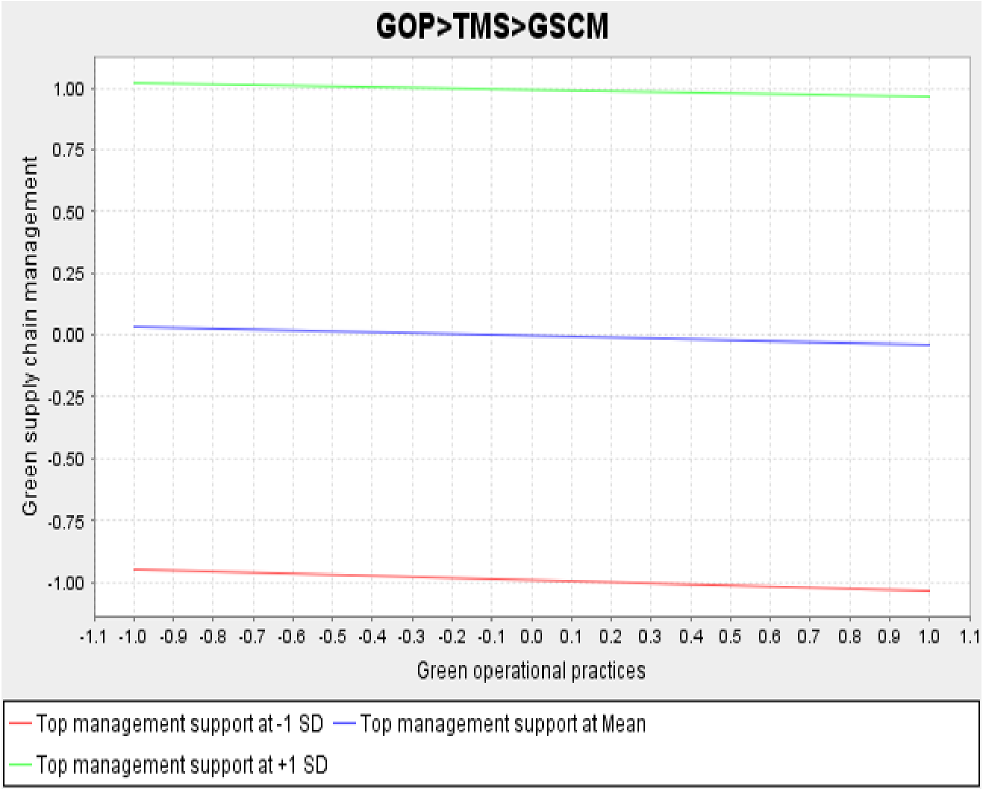

Figure 6: Moderation Effect 3

Source: SmartPLS

5. Discussion and implications

The current research provides empirical evidence that sheds light on the critical role of artificial intelligence (AI) integration as a motivator to improve the green functions and drive Green Supply Chain Management (GSCM) when it comes to small and medium-sized enterprises (SMEs). The experimental findings show that the deployment of AI significantly increases the ability to innovate greenly, organizational behaviors, and organizational culture and, thus, supports the Resource-Based View (RBV) and highlights the strategic significance of distinctive organizational resources. It is necessary to note that despite its strong impact on internal strengths, the direct issue of AI on GSCM is relatively small; this accentuates the idea that technological investments are not enough to ensure sustainable supply-chain results. Therefore, green abilities inside the organization represent the inalienable processes transforming technology adoption to the noticeable improvements in sustainability of the supply chain.

The mediation analysis also highlights the point that green capabilities mediate the relationship between AI adoption and GSCM to some extent. This highlights the salience of organizational structures and processes, e.g. innovation, operational practices, and organizational culture, in facilitating an effective use of AI to achieve sustainability. Also, moderation analysis shows that Top Management Support (TMS) has a decisive effect on the effectiveness of green capabilities to achieve GSCM. High degrees of managerial support increase the impact of green innovation and culture, and low levels limit the transfer of the same into effective supply-chain results, which is aligned with the Upper-Echelons Theory, which suggests that leadership values and commitment have a direct impact on the organizational performance.

In a practical sense, the findings provide useful information to both the SMEs and policy makers. The managers should invest in not only AI technologies but also in other green solutions complementary to it, e.g. eco-innovation, green operational practices, and green organizational culture. It is also important to ensure strong top-management commitment as leadership has a decisive role to play in the instilling of sustainability practices and achievement of sustained GSCM results. Policymakers can also help SMEs by providing incentives to adopt AI, capacity-building programs, and policy frameworks that promote the integration of technology and eco-friendly practices. Collectively, the study demonstrates that achieving sustainable supply-chain performance requires a synergistic strategy, which encompasses the adoption of technology, the organizational capabilities, and the strategic support of leadership.

5.1 Theoretical Contributions

This literary work provides some important theoretical contributions. First, it extends the Resource-Based View (RBV), which proves that the adoption of artificial intelligence (AI) in the organization is a strategic company resource that improves green capabilities, including green innovation capability, green operational practices that are environmentally responsible, and the presence of an environmentally conscious organizational culture, thus, positively impacting green supply chain management (GSCM) in the small and medium-sized enterprise (SME). Unlike other studies that have been more biased in their thinking and approach to understanding green initiatives alone or technology adoption alone, our empirical data explains how synergistic effect is realized when AI and internal capabilities are implemented simultaneously hence enhancing more sustainable supply-chain results.

Second, the research contributes to the current literature regarding organizational leadership within the framework of sustainability using the Upper Echelons Theory. It unveils the fact that Top-Management Support (TMS) mediates the effectiveness of green capabilities. This observation highlights the fact that leadership commitment is an essential contingency variable that needs to remain inseparable to guarantee a successful transformation of technology and organizational resources into concrete GSCM deliverables.

Third, the study presents a subtle analysis of the intersection of sustainability and technology adoption in developing economies, which focuses on the SMEs that are in the environment of emerging markets like Pakistan. Although the existing studies have been primarily conducted within the setting of the mature and established economies, with stable institutions, this research indicates that the introduction of AI, along with green capabilities and leadership, can allow one to increase the level of performance of the supply-chain despite the limited resources and institutional obstacles.

5.2 Practical Implications

The findings of this work have very deep implications to the managers and policy makers who strive to enhance sustainable supply-chain activities among small and medium-entered businesses (SMEs). Empirically speaking, companies ought to rethink the process of introducing artificial intelligence (AI) not only as a new technological improvement but also as a strategic investment that will enhance organizational competence. To successfully leverage AI to achieve sustainability in supply chains, organizations must develop a sustainability-oriented culture, develop green innovation, and entrench eco-conscious operations.

The results also highlight the critical importance of top-management support hence implying that administrators should actively support the idea of sustainability in green supply-chain management (GSCM), whereby the green competencies are transformed into real-life results. To the policymakers, the research highlights the necessity of incentives, training and support mechanisms to enable the alignment of technology and sustainability in SMEs. Together, these observations can serve as a realistic roadmap to show how adopting technology and internal capabilities can be integrated with leadership dedication, which in the end will provide a competitive edge based on sustainable supply-chain management.

5.3 Limitations and Future Research

Although the given research offers valuable information on the connection between AI adoption, green capabilities, and Green Supply Chain Management (GSCM), several limitations must also be noted. First, the study is confined to SME in Pakistan, and this factor may restrict the extrapolation of the results to bigger organizations or companies in other cultural and economic settings. Second, the study is based on the cross-sectional survey data, as it hinders making causal conclusions and the dynamic development of AI implementation and green capabilities through time. Third, even though the research has included some of the most important constructs, such as green innovation, organizational culture, and operational practices, other possible antecedents of GSCM, such as external pressures, regulatory frameworks, and technological infrastructure were not analyzed. Lastly, self-reported measures can provide common-method bias although there are standard survey design and statistics applied.

These limitations can be solved in future studies in several ways. Longitudinal research may be able to give a more in-depth explanation of the causal relationships between AI adoption, green capabilities, and GSCM throughout the years. The comparative analysis of the various industries and countries would contribute to the increased generalizability of results and the determination of contextual elements that affect the success of AI and green practices. Also, the mediating and moderating variables that may affect GSCM, including environmental regulations, pressure of stakeholders, or digital infrastructure, could be examined in future studies to present a more holistic view of what drives GSCM. The incorporation of objective performance measures with the data of the surveys would also enhance the empirical rigor of future studies. The areas would help in enhancing the knowledge on strategic integration of technology, organizational capabilities and leadership in the realization of sustainable supply chain management.

5.4 Conclusion

The present research reviewed implications of artificial intelligence (AI) application into Green Supply Chain Management (GSCM) in small and medium enterprises (SMEs). It clarified the mediating role of green innovation potential, green operational behavior, and green organizational culture and covered moderating role of Top Management Support (TMS). The empirical evidence points to the fact that the adoption of AI is a strong impetus to internal green capabilities that subsequently promote sustainable supply-chain results. Nevertheless, its direct influence on GSCM is relatively small, which highlights the central role of institutional mechanisms in the transformation of technological advances into a practical application. TMS was observed to enhance the input of the green capabilities, especially in the field of innovation and culture. A commitment to leadership became a decisive factor in achieving sustainability goals. At the theoretical level, the study contributes to the Resource-based View by confirming AI as a strategic organizational resource; it also supports the Upper Echelons Theory by proving the moderating impact of managerial support. In practice, the SMEs are suggested to take a complex strategy comprising the implementation of AI, the development of green competencies within the organization, and the maintenance of well-established top-management involvement. Similarly, policymakers ought to help in such integration by providing special incentives and training programs. Conclusively, this research confirms the fact that technology, organizational capabilities, and leadership have a synergistic interaction that can bring about sustainable supply-chain performance. It provides a guideline of how future studies should carry out longitudinal, cross-industry and context-specific studies on the dynamics of GSCM.

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