Received: 11 February 2025 | Accepted: 18 May 2025 | Published: 30 June 2025

Sustainable Trends & Business Research

Vol. 03 | Issue 01 | Pages 22-35 |

Research Article

Leveraging Artificial Intelligence (AI) Capability and Sustainability Orientation for Sustainable Performance: Mediating Role of Green Innovation in Malaysian Manufacturing Sector

Rami Abed Hmaidan[1] | Hafiz Ihsan ur Rehman[2*] | Imran Akram[3] | Afnan Ali Mahmoud Zuagaili[4]

Authors Information

[1] School of Management, Universiti Sains Malaysia, Gelugor, Malaysia.
Email: ramihmaidan@student.usm.my

[2*] Department of Business Administration, University of the Punjab, Gujranwala Campus, Pakistan
Email: h.ihsan@pugc.edu.pk

[3] Department of Commerce, University of the Punjab, Gujranwala Campus, Pakistan.
Email: imran.akram@pugc.edu.pk

[4] School of Management, Universiti Sains Malaysia, Gelugor, Malaysia.
Email: afnanzuagaili@student.usm.my

Declaration of Interests

The authors report no financial or personal conflicts of interest.

Abstract

This study examines the influence of artificial intelligence capability and sustainability orientation on sustainable performance, with green innovation capability serving as a mediating variable. Grounded in the resource-based view, dynamic capabilities theory, and knowledge-based view, the research develops an integrated model to understand how digital transformation and strategic sustainability orientation contribute to long-term environmental and organizational outcomes. Data were collected from 197 respondents representing medium and large manufacturing firms in Malaysia. The model was tested using Partial Least Squares Structural Equation Modeling. The findings reveal that artificial intelligence capability has a significant positive impact on both green innovation and sustainable performance. While sustainability orientation positively influences green innovation, it does not have a direct effect on sustainable performance. However, green innovation capability significantly enhances sustainable performance and mediates the effects of both artificial intelligence capability and sustainability orientation. These results highlight the importance of green innovation as a critical mechanism through which digital capabilities and strategic sustainability efforts are translated into measurable performance outcomes. The study contributes to theory by linking technological and sustainability constructs and offers practical guidance for manufacturing firms aiming to align innovation, digital transformation, and sustainability goals in emerging economies.

Keywords: Artificial intelligence capability, Sustainability orientation, Green innovation capability, Sustainable performance, Manufacturing sector, Digital transformation.

How to Cite this Work:

Hmaidan, R.A., Rehman, H.I., Akram, I., & Zuagaili, A.A.M. (2025), "Leveraging AI Capability and Sustainability Orientation for Sustainable Performance: Mediating Role of Green Innovation in Malaysian Manufacturing Sector", *Sustainable Trends and Business Research*, Vol. 03 No. 01, pp. 22-35.

1 INTRODUCTION

In today's globalized and environmentally conscious business environment, the pressure on organizations to integrate sustainability into their core strategic agendas has grown significantly (Kumar et al., 2025). Environmental concerns such as climate change, pollution, and unsustainable resource usage have led governments, industries, and stakeholders to demand meaningful action from firms (Bocken & Short, 2021). Among the key enablers of this shift are emerging digital technologies - particularly Artificial Intelligence capability (AIC), which offer transformative potential to support sustainable development across industries (Kumar et al., 2025; Zong & Guan, 2024). AIC is broadly defined as an organization's ability to leverage artificial intelligence tools, including machine learning, natural language processing, and predictive analytics, to enhance decision-making, process automation, and innovation (Babatunde, 2024; Naz et al., 2024). Through these technologies, firms can monitor resource use, predict environmental risks, optimize energy consumption, and automate green supply chain processes (Naz et al., 2024). The role of AIC in sustainability has become increasingly prominent in recent studies, which suggest that AIC not only improves operational performance but also facilitates the development of environmentally sustainable solutions (Mondal et al., 2024; Nishant et al., 2020; Rashid et al., 2025). Yet, the understanding of how AIC translates into actual sustainable performance (SP) through innovation pathways, which are remains underexplored, particularly in developing country contexts.

According to Cerchione et al. (2018) complementing technological capabilities, sustainability orientation (SO) represents a firm's strategic commitment to integrating sustainability into organizational culture, objectives, and decision-making processes. Organizations with a high level of SO actively pursue eco-friendly practices, ethical stakeholder engagement, and long-term environmental goals (Ali et al., 2023b; Amir et al., 2021; Khan et al., 2024; Rasheed et al., 2025). SO has been shown to influence how firms develop new products, manage supply chains, and engage with regulatory and social expectations (Hsu et al., 2016). However, although SO is positively associated with SP in theory, there is limited empirical evidence demonstrating the mechanism by which SO leads to tangible environmental and economic benefits. Scholars argue that values alone are not sufficient firms must innovate to translate SO into actionable sustainability outcomes (Cerchione et al., 2018; Hsu et al., 2016; Khan et al., 2024)

In this context, green innovation capability (GIC) emerges as a critical mediator that connects both AIC and SO to SP. GIC refers to the creation, adoption, or improvement of products, processes, and technologies that reduce environmental impact and promote sustainability (Dang et al., 2025). This includes eco-friendly design, renewable energy integration, waste reduction, and low-carbon production techniques. Firms that engage in GIC are often able to improve compliance with environmental regulations, enhance brand reputation, and create market differentiation, all of which contribute to SP (Xu & Zhai, 2020). Importantly, AIC can accelerate GIC by enabling data-driven R&D, optimizing design processes, and enhancing cross-functional collaboration. Similarly, SO can motivate firms to allocate resources and align leadership with innovation goals focused on sustainability (Huang et al., 2020; Xu & Zhai, 2020).

SP is a multidimensional concept that encompasses the economic, environmental, and social dimensions of performance. Rooted in the Triple Bottom Line (TBL) framework ((Elkington, 1997), SP refers to a firm's ability to simultaneously achieve financial profitability, reduce ecological footprints, and fulfill social responsibilities (Amir et al., 2024; Le, 2022; Wu, 2017). While SP is widely promoted in corporate reporting and sustainability frameworks, achieving it requires the integration of advanced capabilities and proactive strategies. Studies have found that firms investing in sustainability not only gain legitimacy and stakeholder trust but also perform better in the long term (Shaukat & Ali, 2024; Treiblmaier, 2019; Windolph et al., 2014). However, the role of digital transformation (i.e., AIC) in enabling this performance through GIC remains an area that warrants deeper investigation.

The Malaysian manufacturing sector offers a compelling setting for examining the interplay of AIC, SO, GI, and SP. As a key contributor to national GDP and employment, manufacturing is central to Malaysia's economic development (Department of Statistics, 2023). Yet, it is also one of the largest contributors to industrial emissions, hazardous waste, and environmental degradation. Recognizing these challenges, the Malaysian government has introduced a range of policy initiatives such as the Twelfth Malaysia Plan, Green Technology Master Plan, and Industry4WRD to encourage green growth and digital adoption in manufacturing. Despite these frameworks, many Malaysian manufacturers, especially small and medium-sized enterprises (SMEs) that struggle to implement effective green strategies due to limited technological capabilities, weak regulatory enforcement, and insufficient incentives (Malaysian Investment Development, 2022).

Moreover, existing studies in the Malaysian context have primarily addressed either sustainability practices or technology adoption in isolation (Appannan et al., 2023; Jayashree et al., 2021; Nisar et al., 2021; Nor-Aishah et al., 2020). Research on AIC has largely centered around productivity and automation, with limited focus on environmental or social impacts (Kumar et al., 2025; Nishant et al., 2020; Rashid et al., 2025). Likewise, studies on SO often examine corporate social responsibility or green reporting without considering the innovation processes that bridge strategy and outcomes (Cerchione et al., 2018; Hsu et al., 2016; Le, 2022). The literature on GIC in Malaysia is still emerging, and little is known about how AIC and SO jointly foster GIC to drive SP. This knowledge gap is particularly relevant for policy and practice as Malaysia aims to position itself as a regional hub for sustainable manufacturing and innovation.

To address these gaps, this study proposes an integrated model to investigate the relationships among AIC, SO, GIC, and SP in Malaysian manufacturing firms. Drawing on the Resource-Based View (RBV) (Barney, 1991), Dynamic Capabilities Theory (DCT) (Teece et al., 1997), and the Knowledge-Based View (KBV) of the firm (Grant, 1997), the study hypothesizes that AIC and SO both positively influence GI, which in turn enhances SP. Thus, the purpose of this study is threefold: first, to examine the direct effects of AIC and SO on GIC; second, to assess the influence of GIC on SP; and third, to investigate the mediating role of GIC between AIC, SO, and SP. By addressing these objectives, the study contributes to both theory and practice. Theoretically, it advances understanding of how digital capabilities and strategic orientations jointly shape sustainable innovation. Practically, it offers insights for managers and policymakers on how to align technology investments and sustainability strategies to enhance performance in resource-constrained environments. The findings may also support the development of targeted training programs, financial incentives, and innovation clusters to accelerate green transformation in the industrial sector.

The structure of the paper is as follows: the next section presents a review of the literature and the development of research hypotheses. This is followed by the methodology section, which details research design, data collection, and analytical procedures. The results section presents the findings of the empirical analysis. Finally, the paper concludes with a discussion of theoretical contributions, practical implications, limitations, and recommendations for future research.

2 LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1 Theoretical Frameworks

This study builds on three key theoretical lenses. First, RBV argues that valuable, rare, and inimitable resources such as AIC and SO form the basis for competitive advantage (Barney, 1991). However, resources alone are insufficient unless firms can transform them into value-creating outputs so here, GIC plays that role. Second, the DCT (Teece et al., 1997) explains how organizations develop, deploy, and reconfigure capabilities such as AIC and GIC to achieve superior performance in rapidly changing environments. Third, the KBV (Grant, 1997) emphasizes knowledge as the primary input for innovation and performance that highlighting the critical role of AIC-enabled learning and SO-driven knowledge-sharing for driving GIC. Yu et al. (2022) extend these arguments by demonstrating that green knowledge management enhances the conversion of AIC into GI. Although green knowledge management is not included in the current model, its indirect influence through organizational learning and data infrastructure remains relevant. Collectively, these theoretical foundations support a holistic view in which GIC acts as a strategic intermediary linking technological and strategic enablers (i.e., AIC and SO) to SP.

2.2 Artificial Intelligence Capability and Sustainable Performance

In the era of Industry 4.0, AIC is increasingly recognized as a strategic resource that enhances a firm's operational and environmental outcomes (Nishant et al., 2020). AIC includes capabilities such as machine learning, natural language processing, and intelligent automation, enabling firms to optimize production processes, monitor emissions, and manage resource efficiency (Rashid et al., 2025; Treiblmaier, 2019; Zong & Guan, 2024). These capabilities empower firms to make environmentally informed decisions, thus directly influencing SP. According to Kumar et al. (2025), AIC supports predictive maintenance and energy optimization systems that reduce carbon footprints and waste. Firms with advanced AIC can use data-driven insights to redesign workflows for maximum sustainability impact (Kumar et al., 2025). Empirical studies also support this claim. For example, (Nishant et al., 2020) found that AI-integrated firms experience significantly better environmental compliance, stakeholder engagement, and long-term economic resilience. AIC enables firms to shift from reactive environmental management to proactive and preventive approaches, helping them align with global sustainability standards such as ISO 14001. Despite the growing evidence, the mechanisms through which AIC contributes to SP are still emerging (Nishant et al., 2020; Rasheed et al., 2025;

Rashid et al., 2025; Treiblmaier, 2019), particularly in the context of manufacturing SMEs in developing countries like Malaysia. Hence, we proposed the following hypothesis.

H1: AIC positively influences SP.

2.3 Artificial Intelligence Capability and Green Innovation Capability

Beyond direct sustainability benefits, AIC also serves as a critical enabler of GIC (Yu et al., 2022). It provides firms with the technological agility to experiment with cleaner processes, simulate alternative product lifecycles, and integrate sustainability metrics into R&D activities (Sethi et al., 2024; Shaukat & Ali, 2023; Uddin et al., 2025; Zhang et al., 2023). Ali et al. (2023a) emphasizes that AIC drives both exploitative and explorative innovation, allowing organizations to manage environmental risks while fostering breakthrough green solutions. For instance, predictive analytics can be used to design energy-efficient logistics or simulate raw material substitution, all of which constitute forms of GIC. Studies show that firms leveraging AIC for innovation are more likely to embed sustainability into product design and manufacturing stages (Babatunde, 2024; Nishant et al., 2020). According to (Rashid et al., 2025), AIC enables green process reengineering and cleaner production by continuously optimizing production lines for environmental compliance. This supports earlier findings by (Nishant et al., 2020), who noted that AI-supported innovation accelerates the adoption of green technologies. Given these points, we proposed the following hypothesis.

H2: AIC positively influences GIC.

2.4 Sustainability Orientation and Sustainable Performance

SO reflects a firm's commitment to proactively incorporating environmental and social concerns into its strategic and operational frameworks (Cerchione et al., 2018). It shapes decision-making, resource allocation, and long-term goal setting by emphasizing ecological responsibility, ethical leadership, and stakeholder engagement (Danso et al., 2020; Zhang et al., 2022). Firms that prioritize SO are more likely to embed sustainability into product development, supply chain practices, and corporate culture, thereby influencing SP directly. Empirical studies have shown that SO contributes positively to SP by driving environmentally responsible practices that reduce regulatory risks, improve brand equity, and enhance operational resilience (Cerchione et al., 2018; Zhang et al., 2022). For instance, Abdullahi et al. (2018) found that Malaysian manufacturing firms with strong SO reported better compliance with environmental standards and stronger stakeholder satisfaction. Similarly, Kuckertz and Wagner (2010) and Khizar et al. (2022) argue that SO enables firms to develop long-term sustainability capabilities, such as cleaner production, sustainable procurement, and community-based initiatives, which improve SP. Moreover, firms with strong SO are more likely to integrate sustainability into core performance indicators, leading to improvements in energy efficiency, employee well-being, reputation, and innovation—all of which contribute to SP (Abdullahi et al., 2018; Borah et al., 2023; Khan et al., 2024; Khizar et al., 2022; Wu, 2017). This direct relationship has also been confirmed in recent studies on emerging economies, where SO was found to significantly predict SP across both large corporations and SMEs (Cerchione et al., 2018; Uddin et al., 2025). Accordingly, the following hypothesis is proposed.

H3: SO positively influences SP.

2.5 Sustainability Orientation and Green Innovation Capability

SO reflects a firm's philosophical and strategic commitment to integrating environmental and social concerns into its long-term vision and operational practices (Zhang et al., 2022). It fosters a values-driven culture that supports experimentation, learning, and collaboration, that all of which are critical to GIC (Cerchione et al., 2018; Crittenden et al., 2011; Rehman et al., 2022). Organizations with high SO are more likely to invest in renewable energy, eco-design, and sustainable supply chains. According to Abdullahi et al. (2018), SO enhances firms' absorptive capacity to engage in sustainability-oriented innovation, particularly within SMEs where leadership plays a pivotal role. Cerchione et al. (2018) found that Malaysian firms with strong SO implemented eco-labeling and life cycle assessments more frequently than those with weak sustainability commitments. Furthermore, SO cultivates long-term stakeholder partnerships, encouraging co-innovation around sustainability challenges (Rehman et al., 2022; Zhang et al., 2022). Therefore, the following hypothesis proposed for current study.

H4: SO positively influences GIC.

2.6 Green Innovation Capability and Sustainable Performance

GIC is widely accepted as a cornerstone of SP (Xu & Zhai, 2020). It includes efforts to redesign products, modify production processes, or implement new business models that reduce environmental harm while sustaining economic viability (Borah et al., 2023; Rehman et al., 2022; Shahzad et al., 2020). GIC initiatives have been linked with improved energy efficiency, waste reduction, regulatory compliance, and enhanced brand reputation. According to Huang et al. (2020), firms that invest in GIC not only achieve cost savings but also gain strategic advantages by appealing to environmentally conscious consumers. Borah et al. (2023) emphasized that GIC leads to improved social equity outcomes through better labor conditions and community engagement. In Malaysia, Shahzad et al. (2020) demonstrated that manufacturing firms implementing GIC practices experienced improved environmental reporting, reduced resource use, and better employee morale with all dimensions of SP. Thus, the following hypothesis proposed.

H5: GIC positively influences SP.

2.7 Mediating Role of Green Innovation Capability

Although both AIC and SO are essential for SP, their impact may be indirect, acting through GIC as a critical conduit (Jayashree et al., 2021; Kumar et al., 2025). Theoretically, this aligns with the RBV, where GIC represents a strategic capability that arises from the integration of tangible like AIC and intangible like SO resources (Barney, 1991). According to DCT, firms must continuously adapt and reconfigure their capabilities to respond to environmental challenges (Teece et al., 1997). GIC functions as a dynamic capability that transforms strategic intent like SO and technical capability like AIC into measurable sustainability outcomes. Empirical studies lend weight to this pathway. Jayashree et al. (2021) and Kumar et al. (2025) both found that GIC mediates the relationship between AIC and environmental sustainability, enabling firms to move from capacity to outcome. Similarly, (Cerchione et al., 2018; Uddin et al., 2025) argue that SO fosters innovation culture, which acts as a mechanism for delivering SP. Therefore, the mediating role of GIC is both theoretically grounded and empirically supported.

H6a: GIC mediates the relationship between AIC and SP.

H6b: GIC mediates the relationship between SO and SP.

Figure 1. presents the theoretical framework of the study.

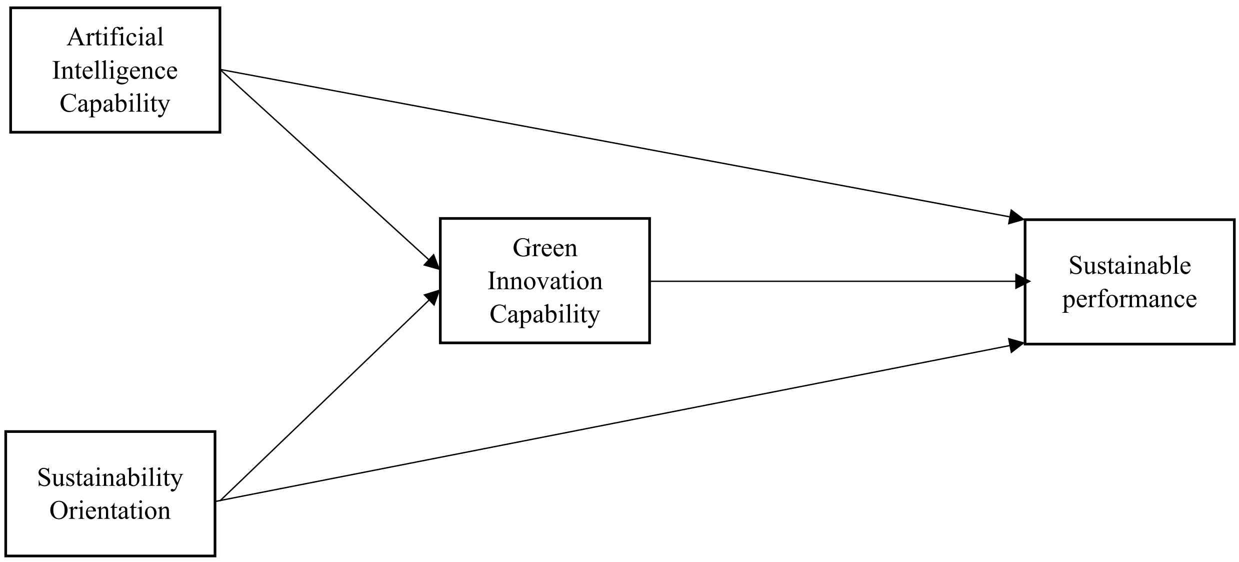

Figure 2. Theoretical Framework

Source(s): *Authors' Own Work.*

3 RESEARCH METHODOLOGY

The study framework was developed based on the resource-based view, dynamic capabilities theory, and knowledge-based view to explain how AIC and SO influence SP, both directly and indirectly through GIC. The target population consisted of employees working in SMEs firms across Malaysia. The manufacturing sector was selected because of its key contribution to national economic growth and its relevance to digital transformation and sustainability policies such as Industry4WRD and the Green Technology Master Plan. A purposive sampling technique was adopted to identify individuals who were knowledgeable about digital capabilities, innovation practices, and sustainability strategies. Respondents included professionals from departments such as sustainability/CSR, operations, R&D, and strategy. A total of 350 questionnaires were distributed through professional networks, industry associations, and LinkedIn. A final sample of 197 valid responses was retained for analysis. This sample size exceeded the minimum threshold recommended by G*Power for medium effect sizes and complex SEM models.

3.1 Measurement Instrument

The structured questionnaire comprised fully adopted and validated measurement scales from prior studies. All items were measured on a 7-point Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). AIC was measured using four items adopted from (Kumar et al., 2025), capturing predictive analytics, automation, data integration, and AI-enabled decision-making. SO was assessed with five items adapted from Cerchione et al. (2018), covering long-term sustainability commitment, stakeholder focus, and environmental value orientation. GIC was measured using five items from Dang et al. (2025), including eco-friendly product design, process innovation, and environmental impact reduction. SP was evaluated through eleven items based on Kumar et al. (2025), encompassing environmental performance, resource efficiency, employee well-being, and social responsibility. All items were used without major modification to ensure consistency with established empirical research.

3.2 Data Analysis Procedure

Data were analyzed in SmartPLS 4.0 following the standard two-step procedure: measurement model assessment and structural model evaluation. For the measurement model, internal consistency was assessed using Cronbach's alpha and composite reliability, both of which exceeded the recommended threshold of 0.70 for all constructs. Convergent validity was confirmed through outer loadings (above 0.60) and average variance extracted (AVE), with all values above the 0.50 threshold. Discriminant validity was established using the Fornell-Larcker criterion and the Heterotrait-Monotrait ratio (HTMT), with all square roots of AVE greater than inter-construct correlations and all HTMT values below 0.85. Multicollinearity was not a concern, as VIF values for all indicators were below 3.3 (Kock & Lynn, 2012). For the structural model, bootstrapping with 10,000 resamples was used to evaluate path coefficients, t-values, and p-values. R^2 values indicated that the model explained a substantial portion of the variance in GIC and SP.

3.3 Ethical Considerations

All ethical protocols were strictly followed. Participation was voluntary, and informed consent was obtained from all respondents. Anonymity and confidentiality were ensured throughout the data collection and analysis process. No personal identifying information was recorded, and all data were used solely for academic purposes.

3.4 Common Method Bias

To address common method variance (CMV), both procedural and statistical remedies were applied. Procedurally, items were placed in a random order, and psychological separation was introduced between predictors and outcomes. Statistically, Harman's single factor test showed that the first factor accounted for less than 43.1% of the variance, indicating that CMV was not a serious concern (Chaudhry & Amir, 2020; Podsakoff et al., 2003). In addition, VIF values were below the cutoff of 3.3, supporting the absence of multicollinearity or CMV (Kock & Lynn, 2012).

4 EMPIRICAL ANALYSIS

The final sample consisted of 197 respondents, with males comprising 52.3% and females 47.7%, reflecting a fairly even gender distribution in Table 1. Most respondents were in the age bracket of 31–35 years (39.6%), followed by those above 35 years (24.9%). Regarding educational attainment, a majority (45.2%) held a Master's degree, and 29.9% held post-graduate qualifications. The participants came from a variety of departments, with Operations/Production (27.9%) and Sustainability/CSR (23.9%) being the most common. R&D/Innovation contributed 20.8% of respondents, indicating that innovation and sustainability-related roles were well represented in the sample. In terms of professional experience, most respondents had 6–10 years of work experience (31.0%), followed by those with 2–5 years (29.9%). This suggests that the respondents were mature professionals with relevant exposure to sustainability practices, digital technology, and innovation processes in manufacturing.

Prior to testing the structural model, the measurement model was evaluated to ensure the reliability and validity of the constructs. This involved assessing internal consistency reliability, convergent validity, and multicollinearity. The evaluation was performed using SmartPLS 4.0, following the two-step approach recommended by Hair et al. (2019a).

Table 1. Demographic Profile of Respondents (N = 197)

Variable	Category	Frequency	Percent (%)
Gender	Male	103	52.3
	Female	94	47.7
Age	Less than 25 years	30	15.2
	26 to 30 years	40	20.3
	31 to 35 years	78	39.6
	More than 35 years	49	24.9
Education	Graduation	31	15.7
	Post-Graduation	59	29.9
	Master	89	45.2
	Other	18	9.10
Department	Sustainability/CSR	47	23.9
	Operations/Production	55	27.9
	R&D/Innovation	41	20.8
	Strategy/Planning	28	14.2
	Others	26	13.2
Years of Experience	Less than 2 years	35	17.8
	2–5 years	59	29.9
	6–10 years	61	31.0
	More than 10 years	42	21.3

Source: Author's Own Work.

Table 2. Measurement Model Assessment Results

Construct	Item	Outer Loading	VIF	Cronbach's alpha	CR	AVE
AIC	AIC1	0.885	2.101	0.837	0.886	0.662
	AIC2	0.877	1.946			
	AIC3	0.698	1.562			
	AIC4	0.780	1.892			
GIC	GIC1	0.794	1.978	0.796	0.860	0.554
	GIC2	0.797	2.000			
	GIC3	0.819	2.114			
	GIC4	0.614	1.352			
	GIC5	0.677	1.533			
SO	SO1	0.707	1.636	0.857	0.898	0.639
	SO2	0.768	1.788			
	SO3	0.811	2.606			
	SO4	0.844	3.276			
	SO5	0.858	2.727			
SP	SP1	0.823	2.817	0.932	0.941	0.594
	SP3	0.740	2.356			
	SP4	0.722	2.693			
	SP5	0.803	2.877			
	SP6	0.826	2.689			
	SP7	0.803	2.054			
	SP8	0.758	2.442			
	SP10	0.719	3.358			
	SP11	0.733	2.713			
	SP12	0.775	2.918			
	SP13	0.766	3.387			

Note. *AIC= Artificial Intelligence Capability; SO = Sustainability Orientation; GI = Green Innovation; SP = Sustainable Performance; CR = Composite Reliability; VIF = Variance Inflation Factor.* ***Source(s):*** *Author's Own Work.*

Internal consistency reliability was assessed using Cronbach's alpha and composite reliability (CR). All constructs exceeded the recommended threshold of 0.70, indicating satisfactory internal consistency (Hair et al., 2019b). Specifically, the Cronbach's alpha values for the constructs ranged from 0.796 (GI) to 0.932 (SP), while the CR values ranged from 0.860 to 0.941, further confirming scale reliability, see Table 2.

Convergent validity was evaluated through outer loadings and Average Variance Extracted (AVE). According to Fornell and Larcker (1981), individual item loadings should exceed 0.60, and the AVE for each construct should be greater than 0.50. As shown in Table 2, the majority of outer loadings exceeded the 0.70 threshold, although a few items (e.g., AIC3 = 0.698, GIC4 = 0.614, GIC5 = 0.677) fell slightly below but remained within an acceptable range expected SP2 and SP9 deleted due to low factor loading. Rest of the items were retained due to their theoretical importance and to maintain the content validity of the respective constructs. All AVE values exceeded the 0.50 cut-off, with values ranging from 0.554 (GI) to 0.662 (AIC), indicating that the constructs explained more than half of the variance in their respective indicators. Multicollinearity was assessed using the Variance Inflation Factor (VIF). All VIF values were below the conservative threshold of 3.3, indicating that collinearity was not a concern in this model (Kock & Lynn, 2012). The highest VIF observed was 3.387 for SP13, which remains within the acceptable range. Hence, the measurement model demonstrated robust psychometric properties, with all constructs showing acceptable levels of reliability and convergent validity. The results confirm that the model is appropriate for testing the structural relationships among the constructs.

Table 3. Discriminant Validity – Fornell-Larcker Criterion and HTMT Ratios

Variable	AIC	GIC	SO	SP	AIC	GIC	SO	SP
AIC					0.813			
GIC	0.314				0.290	0.745		
SO	0.374	0.579			0.322	0.489	0.800	
SP	0.264	0.394	0.341		0.279	0.362	0.315	0.771

Note. *AIC= Artificial Intelligence Capability; SO = Sustainability Orientation; GI = Green Innovation; SP = Sustainable Performance.* ***Source(s):*** *Author's Own Work.*

Discriminant validity was assessed using two complementary techniques in Table 3: the Fornell-Larcker criterion and the HTMT, as recommended by Hair et al. (2019a). According to the Fornell-Larcker criterion, the square root of the AVE for each construct should be greater than its correlations with other constructs. As shown in Table 3, all constructs met this criterion. For instance, the square root of AVE for AIC (0.813) is greater than its correlations with GIC (0.314), SO (0.374), and SP (0.264), indicating satisfactory discriminant validity. Similarly, the diagonal values for GIC (0.745), SO (0.800), and SP (0.771) exceed the respective inter-construct correlations. The HTMT values, presented in the second half of Table 3, were also used to assess discriminant validity. All HTMT values were below the conservative threshold of 0.85 (Kline, 2015), with the highest being 0.489 (between GIC and SO). This further confirms that each construct is empirically distinct from the others. Taken together, the results from both Fornell-Larcker and HTMT analyses provide strong evidence of discriminant validity among the study constructs.

Following the satisfactory validation of the measurement model, the structural model was assessed to test the hypothesized relationships among AIC, SO, GIC, and SP. The analysis included evaluating path coefficients, statistical significance (t-values and p-values), and the mediating role of GIC. Bootstrapping with 10,000 resamples was conducted in SmartPLS 4.0 to determine the robustness of the estimates, see Table 4.

Table 4. Structural Model Results: Path Coefficients and Hypothesis Testing

Hypothesis	Path Relationship	Estimate (β)	SD	t-value	p-value	Supported
H1	AIC → SP	0.162	0.084	1.923	0.027	Yes
H2	AIC → GIC	0.148	0.060	2.449	0.007	Yes
H3	SO → SP	0.143	0.089	1.604	0.054	No
H4	SO → GIC	0.442	0.069	6.373	0.000	Yes
H5	GIC → SP	0.245	0.075	3.262	0.001	Yes
H6a	AIC → GIC → SP (Indirect)	0.036	0.020	1.806	0.035	Yes
H7b	SO → GIC → SP (Indirect)	0.108	0.038	2.836	0.002	Yes

Note. *AIC= Artificial Intelligence Capability; SO = Sustainability Orientation; GI = Green Innovation; SP = Sustainable Performance; SD = Standard Deviation.* ***Source(s):*** *Author's Own Work.*

As shown in Table 4, the direct path from AIC to SP (H1) was found to be statistically significant (β = 0.162, t = 1.923, p = 0.027), indicating that AIC positively influences SP. This supports the premise that firms equipped with strong AI capabilities are more likely to achieve sustainability goals through optimized operations and data-driven decision-making. AIC also showed a significant positive effect on GIC (H2: β = 0.148, t = 2.449, p = 0.007), confirming that AI technologies facilitate green innovation practices within manufacturing firms. These results align with previous studies suggesting that AI adoption enhances firms' capabilities to innovate sustainably.

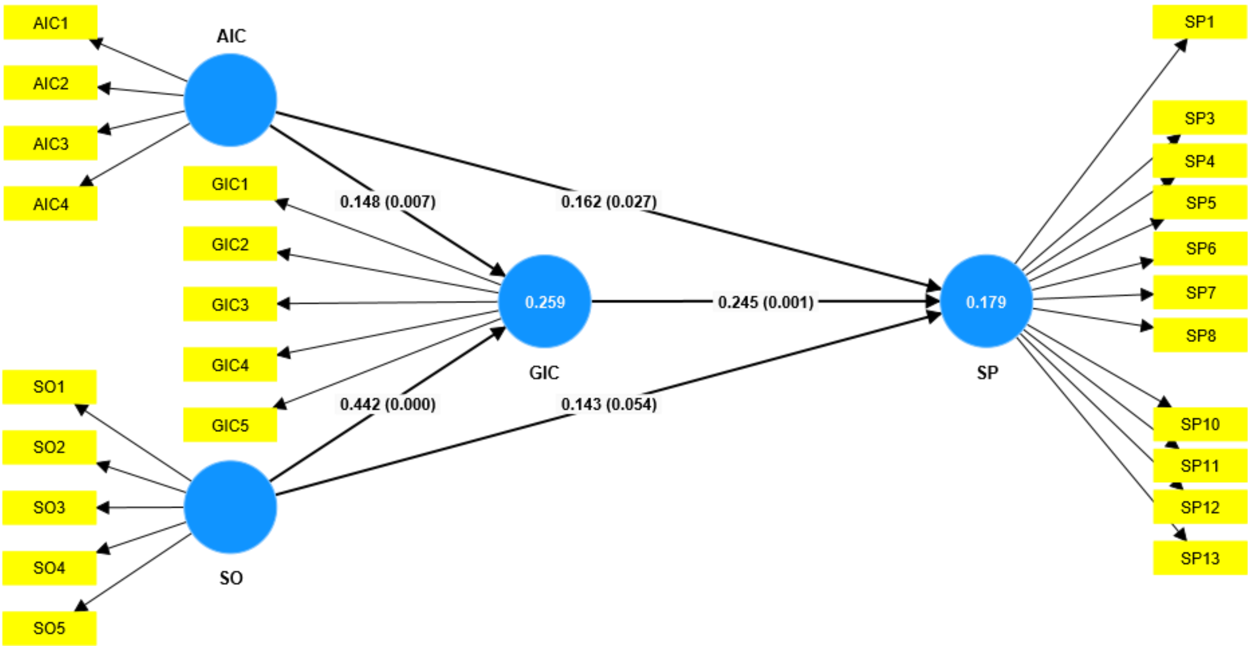

Figure 2. Structural model of the study.

Source(s): *Authors' Own Work.*

In contrast, the direct path from SO to SP (H3) was not statistically significant at the 5% level (β = 0.143, t = 1.604, p = 0.054). Although the relationship was positive, the lack of significance suggests that SO alone may not directly impact SP unless mediated by other organizational processes, such as GIC. Supporting this interpretation, SO exhibited a strong and highly significant positive effect on GIC (H4: β = 0.442, t = 6.373, p < 0.001), suggesting that firms with strong sustainability values are more likely to engage in green product and process innovations. GIC itself was a significant predictor of SP (H5: β = 0.245, t = 3.262, p = 0.001), affirming that green innovations play a direct role in enhancing sustainable outcomes. The analysis also confirmed two significant indirect effects, highlighting the mediating role of GIC. First, GIC partially mediated the relationship between AIC and SP (H6a: β = 0.036, t = 1.806, p = 0.035), indicating that AIC contributes to SP both directly and indirectly through its impact on green innovation. Second, GIC significantly mediated the relationship between SO and SP (H7b: β = 0.108, t = 2.836, p = 0.002), suggesting that SO enhances SP primarily through its influence on GIC rather than via a direct path. Below Figure 2 presents the structural model of the study.

Table 5. Model Fit and Predictive Relevance Indicators

Category	Metric	GIC	SP	Threshold / Interpretation
Model Fit	SRMR	—	—	0.082 (Good Fit; < 0.10)
	NFI	—	—	0.698 (Acceptable Fit; > 0.90 ideal)
Predictive Relevance	Q^2 Predict	0.231	0.097	> 0.00 indicates predictive relevance
	RMSE	0.887	0.960	Lower values indicate better predictive accuracy
	MAE	0.708	0.772	Lower values indicate better predictive accuracy

Note. *GIC = Green Innovation Capability; SP = Sustainable Performance; SRMR = Standardized Root Mean Square Residual; NFI = Normed Fit Index; Q^2 = Predictive Relevance; RMSE = Root Mean Square Error; MAE = Mean Absolute Error.* ***Source(s):*** *Author's Own Work.*

The results presented in Table 5 confirm that the model meets the essential requirements for both model fit and predictive relevance. The SRMR value of 0.082 indicates a good overall model fit, as it is below the recommended threshold of 0.10 (Henseler et al., 2014). Furthermore, the RMSE and MAE values for both GIC and SP were within acceptable limits, further validating the model's out-of-sample predictive accuracy. The slightly higher RMSE and MAE for SP indicate that while the model does have predictive power, the prediction error is relatively higher for SP compared to GIC. Nonetheless, these values remain within a tolerable range for exploratory research.

5 DISCUSSION AND IMPLICATIONS

The purpose of this study was to examine the role of AIC and SO in enhancing SP, with green innovation (GIC) as a mediating mechanism. Using data collected from 197 respondents in the Malaysian manufacturing sector, the findings offer valuable insights into how firms can align technological capabilities and sustainability strategies to improve their environmental, social, and economic outcomes.

5.1 Discussion of Key Findings

The results indicate that AIC significantly and positively affects SP, confirming that firms with advanced AI capabilities can achieve improved sustainability outcomes. This supports previous studies e.g., (Jayashree et al., 2021; Rashid et al., 2025; Zong & Guan, 2024) , which suggest that AI-driven decision-making, automation, and analytics help firms reduce waste, optimize resource use, and comply with environmental standards. Notably, AIC also had a significant positive effect on GIC, reinforcing the idea that AI is not merely a technological tool but a strategic enabler of innovation in sustainability. SO, however, did not show a significant direct effect on SP. This finding suggests that while sustainability values are essential, they may not independently lead to performance outcomes unless translated into tangible actions, such as GIC. This nuance aligns with prior research emphasizing that strategic intentions must be operationalized to produce measurable results (Kumar et al., 2025).

The study further reveals that SO has a strong positive influence on GIC, indicating that firms with deeply embedded sustainability values are more inclined to invest in green technologies, sustainable product design, and eco-friendly processes. This highlights SO as an important cultural and strategic foundation that drives environmental innovation. The positive and significant effect of GIC on SP affirms its role as a key pathway through which organizations can realize their sustainability goals. This aligns with the work of (Singh et al., 2022) and Borah et al. (2023), who emphasized the centrality of innovation in balancing economic growth and environmental preservation. Importantly, GIC was found to mediate the relationships between both AIC and SP, and SO and SP. This confirms the theoretical proposition that GIC acts as a conduit that translates technological capacity and strategic intent into sustainable outcomes. The mediating effect was stronger in the SO–SP relationship, suggesting that sustainability-oriented firms must innovate in order to achieve performance gains.

5.2 Theoretical Implications

This study makes several contributions to the existing literature. First, it expands the understanding of how AIC contributes to SP, an area still underexplored in sustainability research. By demonstrating the mediating role of GIC, the study clarifies the mechanism through which AIC drives sustainability outcomes. Second, the study adds depth to the literature on SO by showing that its impact on SP is not direct but operates through innovation. This reinforces the view that values and orientation alone are insufficient; firms must embed those values into systems and capabilities that foster innovation. Third, the integrated model contributes theoretically by combining three major perspectives: the RBV, which emphasizes the value of AIC and SO as strategic resources; the DCT, which explains how these resources are transformed into GIC; and the KBV, which situates innovation as the central driver of performance. This triangulated theoretical lens offers a comprehensive explanation of how sustainability-driven capabilities function in practice.

5.3 Practical Implications

For practitioners, especially in the Malaysian manufacturing sector, the findings offer actionable insights. Firms aiming to improve their SP should not only invest in digital technologies such as AI but also actively channel those technologies into environmental innovation. The mere adoption of AI tools is insufficient without aligning them with broader sustainability and innovation goals. Leaders and managers should also recognize that fostering a sustainability-oriented culture must be accompanied by a deliberate push toward innovation. Investments in green R&D, cross-functional innovation teams, and sustainability-linked incentives are essential to translate values into measurable outcomes. Policymakers can benefit from these insights by designing programs and policies that encourage digital transformation alongside green innovation. For instance, government grants or tax incentives tied to both AI adoption and eco-innovation projects could accelerate the industry's green transition. Additionally, awareness campaigns and capacity-building initiatives targeting SME managers can help bridge the gap between sustainability awareness and implementation. In the Malaysian context, where manufacturing remains a critical sector for economic development, aligning digital and sustainability agendas is not just beneficial—it is essential. The country's Green Technology Master Plan and Industry4WRD policy frameworks already provide direction, but this study suggests that emphasis should be placed on the intersection of AI capabilities and sustainability-driven innovation to drive real performance gains.

6 CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

This study explored the effects of AIC and SO on SP, with GIC serving as a mediating variable. Based on theoretical foundations, this research developed and empirically tested a structural model using data from 197 respondents in the Malaysian manufacturing sector. The findings demonstrate that AIC has a significant positive influence on SP, both directly and indirectly through GIC. SO also exerts a strong positive effect on GIC, which in turn significantly contributes to SP. However, the direct path from SO to SP was not statistically significant, suggesting that while sustainability-driven values are important, their impact on performance is realized more effectively when operationalized through innovation.

These findings collectively highlight the pivotal role of GIC in translating both technological capabilities and strategic sustainability intent into measurable performance outcomes. The results contribute to the growing literature by showing that SP cannot be achieved by digital transformation or strategic sustainability orientation alone; rather, it requires an integrative approach where AIC, SO, and GIC interact dynamically. This has important implications for managers seeking to enhance SP in resource-constrained environments. Firms must invest not only in advanced AI systems but also in cultivating a sustainability-driven culture and building innovation capability. In practice, this means aligning AIC and SO with concrete green R&D efforts, eco-design strategies, and continuous improvement programs to drive meaningful SP outcomes.

Despite its contributions, this study is subject to several limitations. First, its cross-sectional design restricts causal inference; thus, longitudinal studies would provide a more accurate view of how AIC and SO influence GIC and SP over time. Second, data were drawn exclusively from Malaysian manufacturing firms, which limits generalizability. The findings may not apply equally to service-based sectors or firms operating in different national contexts. Third, while procedural and statistical remedies were applied, the reliance on self-reported data introduces potential for common method bias. Future studies should consider integrating objective measures such as energy savings, emissions data, or verified innovation outcomes to validate reported SP.

Building on these findings, future research can explore additional mediators or moderators that may enrich the understanding of this framework. For instance, organizational size, leadership style, or environmental turbulence could moderate the impact of AIC and SO on GIC. Researchers could also conduct comparative studies across industries or countries to assess how institutional environments affect the strength of these relationships. Moreover, qualitative investigations, such as case studies or interviews, could provide deeper insights into how firms operationalize AIC and SO to drive GIC in everyday business processes. Finally, future models may benefit from integrating other digital capabilities such as big data analytics, blockchain, or IoT to examine their synergistic effects on SP.

REFERENCES

Abdullahi, M. A., Mohamed, Z., Shamsudin, M. N., Sharifuddin, J., & Ali, F. (2018), "Effects of top leadership culture and strategic sustainability orientation on sustainable development among M alaysian herbal-based SME s", *Business Strategy & Development, Vol. 1* No 2, pp. 128-139.

Ali, A. Z., Ameer, I., Faisal, S., & Rauf, H. (2023a), "Forging Sustainable Development: Exploring the Impact of Green Initiatives and Corporate Social Responsibility", *Sustainable Trends and Business Research, Vol. 1* No 2, pp. 76-87.

Ali, K., Amir, M., & Malik, M. S. (2023b), "Strategic motives, proactive environmental strategies and corporate performance: Role of business model innovation and competitive intensity", *Pakistan Journal of Commerce and Social Sciences (PJCSS), Vol. 17* No 2, pp. 348-369.

Amir, M., Azhar, Z., Kishan, A., & Krishnen, L. (2024), "From the implementation of environmental management accounting to organizational sustainability: Does stakeholder integration strengthen it?", *Pakistan Journal of Commerce and Social Sciences (PJCSS), Vol. 18* No 4, pp. 1065-1089.

Amir, M., Iqbal, N., & Tahir, S. (2021), "Impact of Corporate Environmental Responsibility on Firm's Financial Performance: Moderating Role of Organizational Slack and Industry Competition", *Sukkur IBA Journal of Management and Business, Vol. 8* No 2, pp. 76-92.

Appannan, J. S., Said, R. M., San Ong, T., & Senik, R. (2023), "Promoting sustainable development through strategies, environmental management accounting and environmental performance", *Business Strategy and the Environment, Vol. 32* No 4, pp. 1914-1930. doi:10.1002/bse.3227

Babatunde, A. T. (2024), "Driving Innovation through AI and Machine Learning: Exploring the Opportunities of Integrating Artificial Intelligence in Business Intelligence", *Academic Journal of Global Who is who in Academia, Vol. 5* No 1, pp. 1-14.

Barney, J. (1991), "Firm Resources and Sustained Competitive Advantage", *Journal of management, Vol. 17* No 1, pp. 99-120. doi:Doi 10.1177/014920639101700108

Bocken, N. M., & Short, S. W. (2021), "Unsustainable business models–Recognising and resolving institutionalised social and environmental harm", *Journal of cleaner production, Vol. 312* No, pp. 127828.

Borah, P. S., Dogbe, C. S. K., Pomegbe, W. W. K., Bamfo, B. A., & Hornuvo, L. K. (2023), "Green market orientation, green innovation capability, green knowledge acquisition and green brand positioning as determinants of new product success", *European Journal of Innovation Management, Vol. 26* No 2, pp. 364-385.

Cerchione, R., Centobelli, P., & Shabani, A. (2018), "Sustainability orientation, supply chain integration, and SMEs performance: a causal analysis", *Benchmarking: an international journal, Vol. 25* No 9, pp. 3679-3701.

Chaudhry, N. I., & Amir, M. (2020), "From institutional pressure to the sustainable development of firm: Role of environmental management accounting implementation and environmental proactivity", *Business Strategy and the Environment, Vol. 29* No 8, pp. 3542-3554. doi:10.1002/bse.2595

Crittenden, V. L., Crittenden, W. F., Ferrell, L. K., Ferrell, O. C., & Pinney, C. C. (2011), "Market-oriented sustainability: a conceptual framework and propositions", *Journal of the academy of marketing science, Vol. 39* No 1, pp. 71-85. doi:10.1007/s11747-010-0217-2

Dang, H. C. T., Nguyen, P. L. T., Le, P. L. T., Nguyen, T. T. H., & Vu, B. T. (2025), "Impact of Big Data analytics capabilities on sustainable performance of Vietnamese retail companies: the mediating role of innovation", *Journal of Open Innovation: Technology, Market, and Complexity,* No, pp. 100569.

Danso, A., Adomako, S., Lartey, T., Amankwah-Amoah, J., & Owusu-Yirenkyi, D. (2020), "Stakeholder integration, environmental sustainability orientation and financial performance", *Journal of business research, Vol. 119* No, pp. 652-662. doi:10.1016/j.jbusres.2019.02.038

Department of Statistics, M. (2023). *Malaysia Economic Statistics Review: Volume 3/2023*. Retrieved from Putrajaya, Malaysia: https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=100&bul_id=Z1VNRXZUQ0RaWmRSVDRWcFJxZGpJdz09&menu_id=TE5CRUZCblh4ZTZMODZIbmk2aWRRQT09

Elkington, J. (1997), "The triple bottom line for 21st century business", *Journal of Experimental Psychology: General, Vol. 136* No.

Fornell, C., & Larcker, D. F. (1981), "Evaluating Structural Equation Models with Unobservable Variables and Measurement Error", *Journal of Marketing Research, Vol. 18* No 1, pp. 39-50. doi:Doi 10.2307/3151312

Grant, R. M. (1997), "The knowledge-based view of the firm: implications for management practice", *Long range planning, Vol. 30* No 3, pp. 450-454.

Hair, J., Black, W., Babin, B., & Anderson, R. (2019a), "Multivariate data analysis . Cengage Learning", *Hampshire, United Kingdom,* No.

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019b), "When to use and how to report the results of PLS-SEM", *European business review, Vol. 31* No 1, pp. 2-24. doi:10.1108/Ebr-11-2018-0203

Hsu, C.-C., Tan, K.-C., & Mohamad Zailani, S. H. (2016), "Strategic orientations, sustainable supply chain initiatives, and reverse logistics: Empirical evidence from an emerging market", *International Journal of Operations & Production Management, Vol. 36* No 1, pp. 86-110.

Huang, S.-Z., Chau, K. Y., Chien, F., & Shen, H. (2020), "The impact of startups' dual learning on their green innovation capability: The effects of business executives' environmental awareness and environmental regulations", *Sustainability, Vol. 12* No 16, pp. 6526.

Jayashree, S., Reza, M. N. H., Malarvizhi, C. A. N., & Mohiuddin, M. (2021), "Industry 4.0 implementation and Triple Bottom Line sustainability: An empirical study on small and medium manufacturing firms", *Heliyon, Vol. 7* No 8, pp. e07753. doi:10.1016/j.heliyon.2021.e07753

Khan, Z. A., Nawaz, I., & Kamran, H. (2024), "Ecological Strategic Orientation and Sustainable Development", *Human Perspectives of Industry 4.0 Organizations,* No, pp. 170-182.

Khizar, H. M. U., Iqbal, M. J., Khalid, J., & Adomako, S. (2022), "Addressing the conceptualization and measurement challenges of sustainability orientation: A systematic review and research agenda", *Journal of business research, Vol. 142* No, pp. 718-743.

Kline, R. B. (2015). *Principles and practice of structural equation modeling*: Guilford publications.

Kock, N., & Lynn, G. S. (2012), "Lateral Collinearity and Misleading Results in Variance-Based SEM: An Illustration and Recommendations", *Journal of the Association for Information Systems, Vol. 13* No 7, pp. 546-580. doi:DOI 10.17705/1jais.00302

Kuckertz, A., & Wagner, M. (2010), "The influence of sustainability orientation on entrepreneurial intentions—Investigating the role of business experience", *Journal of business venturing, Vol. 25* No 5, pp. 524-539.

Kumar, S., Kumar, V., Chaudhuri, R., Chatterjee, S., & Vrontis, D. (2025), "AI capability and environmental sustainability performance: Moderating role of green knowledge management", *Technology in Society, Vol. 81* No, pp. 102870.

Le, T. T. (2022), "How do corporate social responsibility and green innovation transform corporate green strategy into sustainable firm performance?", *Journal of cleaner production, Vol. 362* No, pp. 132228.

Malaysian Investment Development, A. (2022). *Malaysia Investment Performance Report 2022*. Retrieved from Kuala Lumpur, Malaysia: https://www.mida.gov.my/publications/investment-performance-report-2022/

Mondal, S., Das, S., & Vrana, V. G. (2024), "Exploring the Role of Artificial Intelligence in Achieving a Net Zero Carbon Economy in Emerging Economies: A Combination of PLS-SEM and fsQCA Approaches to Digital Inclusion and Climate Resilience", *Sustainability, Vol. 16* No 23, pp. 10299.

Naz, S., Haider, S. A., Khan, S., Nisar, Q. A., & Tehseen, S. (2024), "Augmenting hotel performance in Malaysia through big data analytics capability and artificial intelligence capability", *Journal of Hospitality and Tourism Insights, Vol. 7* No 4, pp. 2055-2080.

Nisar, Q. A., Haider, S., Ali, F., Jamshed, S., Ryu, K., & Gill, S. S. (2021), "Green human resource management practices and environmental performance in Malaysian green hotels: The role of green intellectual capital and pro-environmental behavior", *Journal of cleaner production, Vol. 311* No, pp. 127504.

Nishant, R., Kennedy, M., & Corbett, J. (2020), "Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda", *International Journal of Information Management, Vol. 53* No, pp. 102104.

Nor-Aishah, H., Ahmad, N. H., & Thurasamy, R. (2020), "Entrepreneurial Leadership and Sustainable Performance of Manufacturing SMEs in Malaysia: The Contingent Role of Entrepreneurial Bricolage", *Sustainability, Vol. 12* No 8, pp. 3100.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003), "Common method biases in behavioral research: a critical review of the literature and recommended remedies", *J Appl Psychol, Vol. 88* No 5, pp. 879-903. doi:10.1037/0021-9010.88.5.879

Rasheed, M., Liu, J., & Ali, E. (2025), "Incorporating sustainability in organizational strategy: A framework for enhancing sustainable knowledge management and green innovation", *Kybernetes, Vol. 54* No 4, pp. 2363-2388.

Rashid, A., Baloch, N., Rasheed, R., & Ngah, A. H. (2025), "Big data analytics-artificial intelligence and sustainable performance through green supply chain practices in manufacturing firms of a developing country", *Journal of Science and Technology Policy Management, Vol. 16* No 1, pp. 42-67.

Rehman, S. U., Bresciani, S., Yahiaoui, D., & Giacosa, E. (2022), "Environmental sustainability orientation and corporate social responsibility influence on environmental performance of small and medium enterprises: The mediating effect of green capability", *Corporate Social Responsibility and Environmental Management, Vol. 29* No 6, pp. 1954-1967. doi:10.1002/csr.2293

Sethi, L., Behera, B., & Sethi, N. (2024), "Do green finance, green technology innovation, and institutional quality help achieve environmental sustainability? Evidence from the developing economies", *Sustainable Development, Vol. 32* No 3, pp. 2709-2723.

Shahzad, M., Qu, Y., Zafar, A. U., Rehman, S. U., & Islam, T. (2020), "Exploring the influence of knowledge management process on corporate sustainable performance through green innovation", *Journal of Knowledge Management, Vol. 24* No 9, pp. 2079-2106. doi:10.1108/Jkm-11-2019-0624

Shaukat, H. S., & Ali, A. J. (2023). *Impact of Environmental Organizational Culture on Green Creativity with mediating role of Green Behavioural Intention: An evidence from Textile industry of Pakistan.* Paper presented at the 2nd International Interdisciplinary Conference on Environmental Sciences and Sustainable Developments Education and Green Economy (IICESSD EGE 2022).

Shaukat, H. S., & Ali, A. J. (2024), "Ethical leadership and firms' sustainability: mediating role of corporate social responsibility in Pakistan's banking sector", *AiBi Revista de Investigación, Administración e Ingeniería, Vol. 12* No 3, pp. 16-23.

Singh, S. K., Del Giudice, M., Chiappetta Jabbour, C. J., Latan, H., & Sohal, A. S. (2022), "Stakeholder pressure, green innovation, and performance in small and medium-sized enterprises: The role of green dynamic capabilities", *Business Strategy and the Environment, Vol. 31* No 1, pp. 500-514.

Teece, D. J., Pisano, G., & Shuen, A. (1997), "Dynamic capabilities and strategic management", *Strategic management journal, Vol. 18* No 7, pp. 509-533.

Treiblmaier, H. (2019), "Combining Blockchain Technology and the Physical Internet to Achieve Triple Bottom Line Sustainability: A Comprehensive Research Agenda for Modern Logistics and Supply Chain Management", *Logistics-Basel, Vol. 3* No 1, pp. 10.

Uddin, M., Hmaidan, R. A., Amir, M., & Shaukat, H. S. (2025), "Driving Efficiency and Sustainability: Integrating Industry 4.0 and Sustainable Human Resource Management Practices in the Logistics Service Sector", *Journal of Posthumanism, Vol. 5* No 6, pp. 817-834. doi:10.63332/joph.v5i6.2152

Windolph, S. E., Schaltegger, S., & Herzig, C. (2014), "Implementing corporate sustainability What drives the application of sustainability management tools in Germany?", *Sustainability Accounting Management and Policy Journal, Vol. 5* No 4, pp. 378-404. doi:10.1108/Sampj-01-2014-0002

Wu, G. C. (2017), "Effects of socially responsible supplier development and sustainability-oriented innovation on sustainable development: Empirical evidence from SMEs", *Corporate Social Responsibility and Environmental Management, Vol. 24* No 6, pp. 661-675.

Xu, J., & Zhai, J. (2020), "Research on the evaluation of green innovation capability of manufacturing enterprises in innovation network", *Sustainability, Vol. 12* No 3, pp. 807.

Yu, S., Abbas, J., Álvarez-Otero, S., & Cherian, J. (2022), "Green knowledge management: Scale development and validation", *Journal of innovation & knowledge, Vol. 7* No 4, pp. 100244.

Zhang, L., Zhang, X. C., An, J. J., Zhang, W., & Yao, J. S. (2022), "Examining the Role of Stakeholder-Oriented Corporate Governance in Achieving Sustainable Development: Evidence from the SME CSR in the Context of China", *Sustainability, Vol. 14* No 13, pp. 8181.

Zhang, P., Li, Z., Ghardallou, W., Xin, Y., & Cao, J. (2023), "Nexus of institutional quality and technological innovation on renewable energy development: Moderating role of green finance", *Renewable Energy, Vol. 214* No, pp. 233-241.

Zong, Z., & Guan, Y. (2024), "AI-driven intelligent data analytics and predictive analysis in Industry 4.0: Transforming knowledge, innovation, and efficiency", *Journal of the Knowledge Economy,* No, pp. 1-40.