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AI-Augmented Knowledge Creation and Sustainable Innovation: Exploring Green Transformation, Integration Stakeholders and Ecosystems

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ABSTRACT

The research explores the impact of Artificial Intelligence-enhanced knowledge creation (AIAKC) on sustainable innovation (SI) in technology-driven manufacturing and service sectors in Pakistan. It focuses on the relatively unexplored intersection of AIAKC, Green Digital Transformation (GDT), Socio-Technical Integration (STI), Sustainable Complexity (SC), and Circular Knowledge Ecosystems (CKE) for organizational sustainability and resilience. A cross-sectional survey of 233 respondents from sectors such as renewable energy, agri-tech, and logistics was conducted. Using Partial Least Squares Structural Equation Modeling (PLS-SEM), the study analyzed direct and mediating effects of the selected variables. Results indicate that AIAKC significantly affects SI, and GDT and STI act as mediators. Moreover, stakeholder complexity and CKE enable and moderate these relationships by supporting adaptive, open learning across organizational boundaries. The findings emphasize the importance of placing digital transformation initiatives in system-level approaches of sustainable value creation. The research is novel as it integrates AI-human collaboration into the circular knowledge ecosystem framework in the setting of an emerging economy. It offers valuable insights into how AI-enabled knowledge processes support sustainable innovation and provides strategic implications for policymakers and organizational leaders who seek to introduce AI responsibly into complex socio-technical systems for long-term resilience.

INTRODUCTION

The past few years have seen a shift in digital transformation initiated by AI, fundamentally changing how knowledge is generated, maintained, and shared within an organization. Due to the global shifts in practices towards sustainability, organizations are not only required to have environmental objectives but also integrate AI functionalities into their knowledge ecosystems to drive sustainable innovation (Aivazidou et al., 2025). AI-augmented systems now serve as enablers of dynamic, context-aware, and intelligent decision-making in the value chains of many industries (Jourabchi Amirkhizi et al., 2025). The merging of

AI and HI (Human Intelligence) into knowledge processes has formed hybrid knowledge ecosystems that represent complex interdependent, and adaptive systems intertwined at the organizational, societal and technological levels (Alam et al., 2023). Earlier studies emphasize the impact of AI technology on the traditional processes of knowledge management (Kumar, 2025), especially toward data-centric approaches for achieving sustainability and open innovation (Li et al., 2020). The intersection of human values, AI, and institutional frameworks has been identified as crucial in the development of responsible circular knowledge flows within socio-technical systems (He et al., 2025). Furthermore, the application of GDT practices, such as eco-friendly infrastructure, carbon-neutral data centers, and sustainable IT policies, has helped to attain environmental goals while fostering digital innovation (Bonetti et al., 2024). Still, the arrangement of these factors into a scalable and coherent knowledge ecosystem remains highly challenging, especially in developing countries like Pakistan, which simultaneously experience digital maturity and sustainability transitions alongside infrastructural and institutional deficits. Multiple researches have stressed the role of SC in ecosystem-based innovation, noting the active participation of customers, regulators, industry associates, and even the broader community in sustainable value co-creation (Zhu et al., 2022). Considered regenerative systems, CKE—systems that perpetually renew value through reuse, sharing, and eco-innovation—are increasingly regarded as vital for sustaining competitive advantage in a resource-constrained economy (Wautelet & Rouget, 2025). Though there is much studying being done on AI, knowledge management, and sustainability, very few empirical studies have comprehensively explored the relationships between AIAKC, digital greening, STI, stakeholder orchestration, and the dynamics of circular ecosystems, particularly within the context of Pakistan's economy. While the global adoption of AI and sustainability initiatives is on the rise, their integration within the organizational knowledge ecosystems remains highly fragmented, creating multidimensional theoretical and practical problems (Zhang et al., 2023). A plethora of works focus on AI in relation to digital transformation or operational productivity (Van der Linde, 2024), some examine sustainability through the lens of CSR or green innovation (Turkeli & Schopuizen, 2019), and only a few try to understand knowledge processes and how AI-enabled synergies could be harnessed for SI outcomes (Saleh et al., 2025). Additionally, Yuen (2023) highlights the issue in developing countries, notably Pakistan, where digital volatility, institutional maturity, governance, and environmental stewardship present such a wide gap that stakeholder engagement and STI complexities are not well explored. These prior empirical investigations have tended to concentrate on these with an isolated view, without capturing the dynamic interplay between GDT, SC, and knowledge regeneration through AI-HI collaboration in an ecosystemic framework. This gap stifles efforts at developing scalable context-sensitive frameworks outlining the role of AI-augmented knowledge systems in global sustainability agendas across organizational diversity. As such, understanding the multi-layered interplay between AI, knowledge creation, and sustainability in circular and socio-technically integrated ecosystems remains underdeveloped.

This study investigates the synergistic effect of the variables unified within a single framework situated in the context of an industrial setting in Pakistan, thus addressing the gap these conceptual and empirical silos have created. In defending these claims, the study outlines important gaps in both theory and practice. First, it claims that the theory of integration of AI with human intelligence, knowledge ecosystems, and SI, lacks sufficient literature focused on the interplay of organizational and ecosystem levels. Moreover, it integrates underexplored constructs such as GDT, STI, SC and CKE, which are critical to developing sustainable paradigms of knowledge management in a digital context. On the other hand, the study argues that AI sustainability enablers and barriers will provide practical guidance for innovation managers, sustainability strategists, and policymakers in emerging markets. This context makes it possible for these conversations to happen, further enriched by Pakistan's contribution from the periphery on global issues like digital convergence and the environment. With world-leading digital penetration rates in Pakistan, increasing structural constraints, diverse stakeholders, and a fast-ramping awareness of the environmental issues, this research reveals the need for firms to reconsider investment strategies for AI as a tool for responsible enabling innovation. Different from previous studies, where AI and sustainability initiatives were assumed independent or modeled in a linear fashion, this research approaches the relationship as an ecosystemic intersection—dynamic, complex, with emergent feedback loops and co-evolution. Its cross-pollination with the theories of socio-technical systems, knowledge management, and circular economy is what distinguishes it and aids in framing the model for both developed and developing economies. This study addresses the gap in the literature concerning knowledge management in conjunction with sustainable innovation by putting forth several unique ideas. First, it defines AIAKC within the scope of knowledge ecosystems as an SI enabler. Second, it empirically tests the mediating and moderating influences GDT, STI, SC, circularity, and the embodied relations hold within this relationship—thereby exposing the systemic sustainability levers. Third, it proposes an ecosystem theory-based multi-level perspective for the analysis of technological micro phenomena and their translation into sustainable macro outcomes. Finally, it broadens the emerging market focus of AI-sustainability research by formulating perspectives that posture digital policy and ESG framework guidance for Pakistan and analogous territories. In pursuit of these objectives, the author employed a quantitative approach with a cross-sectional survey design. Data collection utilized a sample of 233 participants from Pakistan's emerging industries, comprising renewable energy, sustainable manufacturing, fintech, and agri-tech sectors. Participants were chosen on the basis of their roles in organizational sustainability and digital transformation so as to align with the study constructs. A structured questionnaire was designed using validated measures from previous research on AI integration, knowledge management, GDT, socio-technical systems, stakeholder theory, and circular economy. The instrument underwent several rounds of pre-testing before full-scale administration. Analysis of the data was performed using Partial Least Squares Structural Equation Modeling (PLS-SEM), which is suitable for evaluating exploratory models with complex constructs and mediation relationships. Construct validity was evaluated by measurement model sieg und durch grp. Confirmatory factor analysis, where structural relationships were assessed employing bootstrapping techniques. Rounds of additional analyses estimating different hypotheses leading to the initial model were conducted to assess validity and reliability.

Theoretical Background

The Knowledge-Based View, addressing the growing importance of artificial intelligence technologies for business value generators, suggests that the incorporation of AI into organizational knowledge systems holds unprecedented transformational potential, requiring new theories in business management with respect to sustainability transitions. The AI-based technologies revolution throughout every sector is significant because it transforms how information is synthesized, applied, and managed. As modern ecosystems are being created for knowledge, its creation, aggregation, and different stages of growth, parallel systems and synergies with interfaces sustain transitions toward more sustainable paradigms. This paper addresses gaps from their intersection through three complementary lenses: KBV with Grant (2015), Socio-Technical Systems Theory (Appelbaum, 1997), and Stakeholders Theory (Freeman, 1984). This multi-focal combination explains that the synthesis of AI technologies and knowledge is bound to reshape the entities working for socio-economic development, including scientific activities, enhancing citizen participation in governance, and nurturing intelligence external to governmental structures crucial for self-sustainable prosperity. The Knowledge-Based View (KBV) claims that knowledge is the most important resource a firm can strategically control, and the competitive advantage of a firm is derived from knowledge creation, sharing, and application better than her competitors (Dziubaniuk et al., 2024). In contemporary knowledge ecosystems, AI emerges as one of the most powerful facilitators of this process by automating knowledge discovery, augmenting human decision-making, and enabling real-time learning and adaptation (Barbero & Ferrulli, 2023). Algorithms of AI like natural language processing, machine learning, and generative modeling empower firms to surpass the cognitive boundaries of knowledge creation, spurring on data-driven and sustainability-focused innovation (AI-Akash et al., 2024). Regardless, KBV also suggests that knowledge creation needs to be integrated in organizational routines and social practices—something that deeply relates to the circular knowledge ecosystems concept where knowledge flow is non-linear, iterative, and regenerative with feedback loops (Ahmadov et al., 2023). The STS Theory becomes crucial in understanding how AI-augmented knowledge is operationalized. This theory focuses on the integration of social and technical subsystems within an organization and posits that the optimal AI effect is achieved when there is balance between technology and human factors, including behaviors, norms, and cultures (Baumle et al., 2023). In the contemporary digital world, socio-technical integration is more than the application of technology; it is the purposeful alignment of AI with human decision-making, ethics, and contextual knowledge (Ashour et al., 2024). A range of empirical research demonstrates that socio-technical misalignment contributes to poorly designed AI implementations with unsustainable results, particularly at greater levels of institutional sophistication or infrastructural constraints (Aldarawsheh et al., 2024). This is especially applicable to Pakistan, where different degrees of digital sophistication exist alongside multifaceted institutional and cultural logics. Socio-technical alignment therefore stands out as an essential precondition for the fostering of GDT and circular innovation in the innovation-knowledge ecosystems. Complementing these theories, Stakeholder Theory approaches the organization's impact on other actors with an ecosystemic outlook by emphasizing the importance of several stakeholders on the strategy and the organization's result (Freeman, 1984). In ecosystems focused on sustainability, where the ecosystem encompasses employees, customers, community members, environmentalists, and other such captains, the stakeholder roles are heightened due to concerns regarding the ethics of AI use, transparency, and innovation (Marion et al., 2025). Recent works highlight that the complexity of stakeholders with differing expectations and imbalanced power relations can either facilitate or hinder the shift towards sustainable practices of using technologies (Jourabchi Amirkhizi et al., 2025). In CKE, stakeholders are value creators through active participation and not mere passive consumers. They engage in participatory innovation, knowledge creation, and environmental stewardship (Kumar, 2025). Therefore, examining how stakeholder complexity affects AIAKC and SI is crucial to construct adaptive and resilient knowledge ecosystems. Aligned with the other theoretical frameworks, considering this integration provides a more thorough explanation of the mechanisms behind the evolution of AI-enabled knowledge systems concerning sustainability and digital transformation. The KBV emphasizes the importance of knowledge and, hence, the role of dynamic capabilities to exploit AI-induced innovations. While Stakeholder Theory places this interaction within an ecosystem of dependencies and conflicts with a collective value creation focus, STS theory reflects on the socio-organizational infrastructures necessary for AI-HI collaboration. Together, these theories construct a powerful framework for analyzing how AIAKC promotes SI under GDT's mediating impact, STI's moderating influence, SC's orchestration stance, and the regenerative logic of CKE. By bridging the gaps among these theoretical frameworks, this study not only deepens the discourse on sustainability, digitalization, and knowledge orchestration, but more importantly, addresses the empirical problems within the new industrial paradigm of Pakistan.

AI-Augmented Knowledge Creation and Sustainable Innovation.

AIAKC significantly helps to enable SI by increasing the organization's capability for knowledge creation, knowledge refinement, and knowledge application in sophisticated multi-problem environments. The availability of AI tools for data time-critical processing, analytic forecasting, and reasoning automation enriches the learning ecosystem, which in turn accelerates sustainable solutions (Budhwar et al., 2023). Dreidi et al. (2024) argue that AI knowledge systems improve eco-innovation by enhancing firms' abilities to sustain their innovation capacity through pattern recognition integrated with circular economy constructs. Also, Ghobakloo et al. (2024) emphasized that knowledge management systems based on AI profoundly accelerate environmental innovation strategy by integrating technological and sustainability synergies for eco-advancements. Iapaolo et al. (2024) further argued that AI in knowledge workflows increases accuracy in decision-making, which in turn facilitates fast-tracking the design of resource-efficient and greener innovations. Finally, Li et al., (2020) confirm that active environmental innovation is accelerated by intelligence in embedded learning ecosystems because organizations are empowered to anticipate sustainability challenges and co-design solutions oriented towards those challenges. Hence, introducing AI within knowledge processes is not solely an operational advantage; after understanding the profound implications these changes can make, organizations can frame them as strategic shifts that reframe the entire landscape of SI in a meaningful and enduring way. Following these studies, the hypothesis is then formulated. At the same time, synthesizing these theoretical lenses leads to the conceptual framework shown in Figure 1. This framework captures the proposed relationships among AIAKC, GDT, STI, SC, CKE, and SI.

H1: AIAKC positively influences SI.

AI-augmented Knowledge Creation and Green Digital Transformation

AIAKC notably propels GDT forward by enabling smart environmental process decisions and automation aligned with sustainability objectives. With AI systems, organizations can capture environmentally relevant data, perform analytics, model carbon-efficient scenarios, and optimize their digital infrastructures to achieve green goals (Liao et al., 2023). These systems assist in emitting emissions as well as digitally restructuring processes to improve energy and fuel use visibility through their emission impacts (Smuts & Van der Merwe, 2025). Firms that integrate AI into their knowledge-based systems are more likely to adopt green technologies such as smart energy systems, sustainable cloud computing, and AI waste reduction systems (Martinez-Pelaez et al., 2024). Smolka and Boschen (2023) stressed AI's contribution to knowledge creation as a driver of the profound transformation of business processes around digital value chains with a focus on green value. Further, Gembali et al. (2024) described the AI-augmented green ghetto practices as the green supply chain reconfiguration enablers for the complex networked digital sustainability transition. Lastly, He et al. (2025) found that AI-driven organizational learning enhances organizational culture and technological readiness, which nurtures the leadership for the digital green initiatives. The studies in 2024 seem to support the conclusion that AIAKC emerges as a GDT enabler. After these studies, the following hypothesis was formulated.

H2: AIAKC positively influences GDT.

AI-Augmented Knowledge Creation and Socio-Technical Integration

AIAKC promotes seamless STI by integrating technology with human work, organizational practices, and collaborative decision frameworks. Organizational embedding of AI-powered knowledge tools increases the interaction of human skills with intelligent systems, therefore enhancing flexibility, improving teamwork, and fostering collective creativity (Mollah et al., 2024). Turkeli & Schopuizen (2019) noted that AI-facilitated knowledge infrastructures enhance systems thinking by enabling the cross-dialogue and transparent flow of communication and knowledge among the technical staff, managerial levels, and external experts. This integration allows the bridging of socio-technical divides and fosters the synergy between social structures and digital technologies (Vargas-Hernandez et al., 2023). In the same vein, Zhou et al. (2024) ascertained that knowledge creation powered by artificial intelligence enhances interdepartmental collaboration and responsiveness of socio-technical systems to evolving organizational needs. In addition, it is argued that AI technology constitutes cognitive partners and not subcontractors, as they provide support within hybrid intelligence systems where automated machine outputs and human evaluation are correlated (Van der Linde, 2024). In this way, such systems are required to achieve socio-technical equilibrium in digital ecosystems. Lastly, Yuen (2023) AI-based knowledge integration provides for the co-evolution of social and technical capabilities, enabling firms to devise agile socio-technically aligned innovation frameworks and responsive structures to adaptive demands. All these combined snapshots advocate the notion that AIAKC is a fundamental STI driver. After these studies, the following hypothesis was formulated.

H3: AIAKC positively influences STI.

AI-Augmented Knowledge Creation and Stakeholder Complexity

AIAKC transforms SC by allowing organizations to understand, predict, and strategically act on the diverse segment through intelligent insights. Systematic stakeholder interdependencies, emerging expectations, and value conflicts stemming from blurred qualitative data relationships, as well as unstructured information, are identified through AI's ability to analyze large datasets, which enhances stakeholder mapping and strategic alignment (Alam et al., 2023). Increased AI-capacity fostering participatory knowledge ecosystems has accelerated dynamic engagements with stakeholders, keeping traditional interactions at the periphery by reinventing them into context-optimized, intelligent, and responsive engagements (Bonett et al., 2024). Stakeholder relation ambiguities in multi-actor scenarios are lessened by AI's clarity augmentation concerning knowledge and the precision of decisions made, thus translating improved transparency to multi-vocal contexts. Additionally, He et al. (2025) argue the potential of intelligent knowledge systems in actively managing stakeholder plurality by exposing latent interconnections, addressing forecasted concerns, and innovating inclusively at lower thresholds. Consequently, the ability to seamlessly orchestrate value co-creation while maintaining strategic alignment within intricate blended ecosystems is acquired (Hearth Pathirannehelage et al., 2025). In like manner, Johnson et al. (2022) highlight the responsive capabilities of AI-based knowledge tools toward stakeholder integration, as sharpened inclusivity edges the agility with which legitimacy, influence, and expectations are dynamically managed. Altogether, these elucidations fortify the proposition of AIAKC's significant impact towards leveraging and navigating SC to harness sustainable advantage. Upon completion of the studies, the following hypotheses were determined:

H4: AIAKC has a positive influence on SC.

AI-Augmented Knowledge Creation and Circular Knowledge Ecosystems

AIAKC is important for developing and advancing CKE because it encourages the continual creation, refinement, and application of knowledge flows throughout and beyond the organization. As AI systems progressively automate learning loops, knowledge identification and capturing, along with instantaneous knowledge flow, provide the infrastructural requirements for regenerative and self-sustaining innovation ecosystems (Jourabchi Amirkhizi et al., 2025). Recent research focuses on how circularity enabled by AI-architected knowledge systems is brought about through redundancy minimization, increased interoperability, flow-agnostic cross-silo interactions, and enhanced learning across sectors (Saleh et al., 2023). These systems enable firms to maintain value across firm-specific innovation cycles by seamlessly linking historical knowledge with adaptive, responsive future decision frameworks (Iapaolo et al., 2024). Further, Hermann et al. (2022) noted the role of AI-based platforms in supporting knowledge circularity through cognitive automation and semantic content filtering. They allow organizations to leverage a broad spectrum of external knowledge inputs, including from their stakeholders, partners, and even competitors. This is in line with principles of circularity—reuse, reinvention, and regeneration—in a digitally driven and sustainable innovation environment (Gembali et al., 2024). In addition, Ghobakloo et al. (2024) showed that knowledge flow is enhanced across ecosystems by AI systems through the dynamic linking of decentralized actors, critical to circular ecosystems for co-creation, problem-solving, and resource efficiency. These engagements guided by AI enhance resilience and sustainability by reducing the waste of knowledge resources while maximizing the shared value (Kumar, 2025). Hence, the framework of AIAKC acts as a facilitator for nurturing dynamic CKE that propels enduring innovation and sustainable growth. After these studies, the following hypothesis was formulated.

H5: AIAKC has a positive influence on CKE.

Green Digital Transformation and Sustainable Innovation

GDT enables ecologically sustainable SI by incorporating environmental considerations into primary strategic digital thinking, process frameworks, and technological backbone systems. Adoption of digital elements such as IoT, AI, and blockchain allows for more responsible innovations to be conceived and executed considering both economic and environmental aspects, owing to the convergence of sustainability principles and digital capabilities (Jourabchi Amirkhizi et al., 2025). There is emerging evidence that GDT enhances SI by enabling more efficient data-based resource management decision processes, predictive sustainability actions, and the development of green business models (Dreidi et al., 2024). Companies adopting GDT are increasingly able to simultaneously achieve positive environmental outcomes and leverage innovative opportunities to strengthen competitive positioning (Alam et al., 2023). In addition, Baumle et al. (2023) argued that green digitalization enables the reconfiguration of value chains of firms toward greener directions allowing eco-design, green reverse logistics, and low-carbon value-adding operations, which in turn translates directly to SI outputs. From an organizational learning standpoint, GDT fosters the development of environmentally proactive organizational cultures, where sustainability-driven innovations and continuous problem-solving become standard (Dreidi et al., 2024). This cultural transformation strengthens enduring solutions to sustainable challenges. GDT serves as both a technological and strategic lever, allowing companies to develop innovations in their processes that achieve goals in sustainability in the environmental, social and economic contexts simultaneously (Liao et al., 2023). After these studies, the following hypothesis was formulated.

H6: GDT has a positive influence on SI.

Socio-Technical Integration and Sustainable Innovation

STI is important for adaptive Sibby to balance the acceleration of technologies with human-centered principles, culture, and organizational structures. Unlike purely technological measures, STI innovations are social, ethical, and practical adoptions, thus improving their sustainability shift (Herath Pathirannehelage et al., 2025). As organizations bring social elements, e.g., collaborative knowledge practices, participation of cross-functional teams, and inclusion of other stakeholders, into the technical systems frameworks, they improve their ability to create enduring contextual relevance and innovative answers (Bilgram & Laarmann, 2023). This alignment creates not only social acceptability and responsibility but also technical achievability (Budhwar et al., 2023). Alam et al. (2023) assert that information socio-technical systems integrating softened those sustainable innovations are achieved mostly through their combining with technological change, politically active governance institutions paradigm shift participatory governance change, and accompanied structure governance. Furthermore, Block et al. (2023) provides that such incorporation is essential to boost organizational learning and knowledge recombination because of innovations that are sustainably proven. As co-designing green solutions with employees, customers, and even policymakers helps to systemically change them, STI facilitates change (Aivazidou et al., 2025). This approach, where all the stakeholders are involved, aids in making the sustainable innovations more relevant, scalable, and even more resilient to the changing environmental and social challenges (Andersson et al., 2024). After these studies, the following hypothesis was formulated.

H7: STI positively influences SI.

Stakeholder Complexity and Sustainable Innovations

Strategic management of SC, as defined by the multitude of expectations, dynamic interaction flow, and interests of various parties, can enable SI. Supported by more recent scholarship, complexity is not viewed as a constraint; rather, it enables creative tension, collaborative synergetic problem-solving, and paradigm shifts (Almagharbeh et al., 2025). SC-embracing organizations are typically more active in conversations with deeper decision-making scopes and in cross-boundary coalitions, which leads to better understanding and better innovation (Dziubaniuk et al., 2024). The greater worldview that is retrieved from different values enables social, environmental, and economical problems to be solved in a sustainable way and simultaneously (Hearth Pathirannehelage et al., 2025). As Jourabchi Amirkhizi et al. (2025) argue, innovation is better diffused and more legitimate when diverse stakeholders engage in the processes due to trust, transparency, and shared purpose. In sustainability contexts, public good alignment and stakeholder value integration into innovation process architecture are essential for long-term viability (Martinez-Pelaez et al., 2024). Further, Wautelet & Rouget (2025) claim organizations that embrace SC into their innovation ecosystems have a greater anticipation capability for societal trends, regulatory changes, and value co-creation through innovation focused on sustaining value. This culminates in innovations that are both technically feasible and socially innovative, as well as environmentally relevant innovations (Vargas-Hernandez et al., 2023). After these studies, the following hypothesis was formulated.

H8: SC has a positive influence on SI.

Circular Knowledge Ecosystems and Sustainable Innovation

CKE are complex adaptive systems, which focus on the knowledge exchange, regeneration, and reintegration across organizations and institutions. These ecosystems are highly important in accelerating SI by fostering iterative, open cooperative, and co-evolving learning aligned with circular economy concepts (Smolka & Boschen, 2023). Knowledge flow is not CKEs' strong suit; rather, it is feedback loops processing knowledge from failures and reception in the market to integrate stakeholder knowledge to retune innovation outputs (Marion et al., 2025). Studies by Johnson et al. (2022) and Iapaolo et al. (2024) together focus on the circularity of knowledge in resource-efficient, flexible, and resilient innovation models crucial for enduring sustainability. Furthermore, CKEs foster transdisciplinary collaboration among academia, the industry, government, and civil society, facilitating transformative insights that challenge normative assumptions and enable radical pathways toward sustainability (Hermann et al., 2022). Such wider participation increases the system's absorptive capacity, which enables faster adaptation to environmental changes and stakeholder demands (Ghobakloo et al., 2024). Embedding sustainability into the ideation, design, and deployment phases drives systems innovation in circular contexts, according to Aivazidou et al. (2025). Consequently, innovations originating from such ecosystems are more likely to attain scale, gain social acceptance, and have environmental alignment (Aldarawsheh et al., 2024). These studies led to the formulation of the following hypothesis.

H9: CKE positively influences SI.

Mediating Role of Green Digital Transformation

AIAKC has strategically enabled GDT by automating, enhancing, and organizing knowledge in a manner that supports the attainment of ecosystem objectives. Clever systems are able to assist firms in reengineering processes, digitizing green workflows, and sustaining innovation through more sophisticated sustainable knowledge infrastructure (Ashour et al., 2024). As AIAKC provides the cognitive and technological foundation, GDT is AIAKC's operational counterpart, which translates the cognitive intelligence into actionable, so-called eco-innovative strategies (Block et al., 2023). Bilgram and Laarmann's study sustains the growing evidence suggesting that the interaction between insights derived from AI and digitally integrated green technologies propels business performance and extended value creation frameworks (Bilgram & Laarmann, 2023). GDT exploits the results of AI-enhanced systems to embed carbon-neutral technologies, eco-analytics, and a green supply chain framework, which vitally determine the components of sustainable innovation (Barbero & Ferrulli, 2023). In this way, GDT serves as an additional transformational layer of eco-innovation, which enables the translation of abstract knowledge into concrete green architectural capabilities (Dreidi et al., 2024). In addition, GDT provides the elasticity and scalability that support the agile prototyping and rapid testing of sustainable products and processes (Gembali et al., 2024). Firms that transform digitally through green pathways are more likely to produce outcomes that deliver economic benefits while being socially responsive and environmentally responsible (Kim et al., 2024). In this case, AIAKC by itself may not completely foster SI unless its knowledge outputs are implemented via GDT. Therefore, the GDT mediating effect captures this global impact of AI knowledge conversion essential for the sustainable impact. After these studies, the following hypothesis was formulated.

H10: GDT mediates the relationship between AIAKC and SI.

Mediating Role of Socio-Technical Integration

AIAKC enhances organizational intelligence through deeper insight, foresight, and contextual intelligence. Nonetheless, the conversion of such knowledge into sustainable innovation relies on aligning technology's possibilities with human systems—this is where STI comes into play (Alam et al., 2023). STI ensures that human agents, digital actors, and structural processes transcend interoperability barriers. Such synergy enables the application of AI knowledge in innovation ecosystems (Dreidi et al., 2024). STI merges the cognitive fracture that exists between data-centric intelligence and its execution by integrating AI outcomes into workflows, collaboration, and dynamic organizational structures (Saleh et al., 2025). Zhu et al. (2022) indicated that STI serves an important function for inclusive and sustainable system-wide innovation. The distribution of AI knowledge within integrated socio-technical systems encourages collective innovation practices, fostering decentralized decision-making and agility in responding to environmental challenges (Wavtelet & Rouget, 2025). Furthermore, STI improves the organization's absorptive capacity—the organization's ability to recognize, assimilate, and apply valuable knowledge—integrating sustainability into innovation efforts (Turkeli & Schopuizen, 2019). Even the most sophisticated AI-augmented systems could improve STI (Smolka & Boschen, 2023). Thus, STI acts as a mediator by implementing AIAKC into the organizational structure in a manner that enables coherent and scalable SI. After these studies, I proposed the following hypothesis.

H11: STI mediates the relationship between AIAKC and SI.

Mediating Role of Stakeholder Complexity

As much as AIAKC provides an organization with sophisticated analytical foresight and real-time decision-making tools they can rely upon to drive innovation, how well diverse stakeholder interests are managed often SC determines how far AIAKC can take the organization. SC encapsulates the diversity and interdependence, as well as, at times, the colliding motives of internal and external stakeholders within and beyond defined sustainability ecosystems (Block et al., 2023). AIAKC systems are capable of producing broad-spectrum knowledge that illuminates the needs, behaviors, and pressures of diverse constituents and stakeholders (He et al., 2025). But having this intelligence and converting it to innovation requires dynamic orchestration among stakeholders. Their various constituents compel organizations to deeper dialogue, co-creation, and boundary-spanning interactions aside from engagement on and within the organization. SC does mediate in that regard, bridging the gap between AI and contextually relevant inclusive innovation (Hearth Pathirannehelage et al., 2025; Ghonim & Awad, 2024). Other studies (Liao et al., 2023; Rajjan et al., 2024) have pointed out that in multi-stakeholder settings strategic participation maximizes knowledge alignment with intended governance outcomes. Moreover, SC promotes the systems thinking that integrates AI-driven innovations with sustainable developmental objectives within collaborative frameworks (Marion et al., 2025). As AIAKC improves transparency and accountability within the entire value chain, SC facilitates the conversion of this transparency into trust-based innovation networks (Liao et al., 2023). In this regard, SC is not only a constraint but also a crucial mediating factor that conditions the effects of AIAKC on SI by configuring the knowledge sharing, negotiating, and implementation processes across contending stakeholder domains. With these insights in mind, the hypothesis was constructed as follows:

H12: SC mediates the relationship between AIAKC and SI.

Mediating Role of Circular knowledge Ecosystems

AIAKC can create value in the form of a potent competitive advantage by innovatively transforming and applying knowledge. Together these processes help a firm streamline knowledge creation, synthesis, and knowledge application at an unparalleled speed, scale and agility. For knowledge to transform into SI, it must be assimilated in systems like CKE that aid in knowledge circulation, reuse, and collaborative refinement (Jourabchi Amirkhizi et al., 2025). CKEs are dynamic structures that are feedback driven and where knowledge is shared and adapted across stakeholders, technologies and functions (Gembali et al., 2024; Saleh et al., 2024; Din et al., 2024; Saad et al., 2025; Qadeer & Awad, 2025; Qadeer et al., 2025; Wahid et al., 2025). CKEs protect against knowledge isolation when new knowledge is produced by AI systems. Instead, CKEs guarantee that knowledge is disseminated in an iterative fashion, which is important for innovation cycles based on ecological, social, and economic sustenance (Dziubaniuk et al., 2024). It has been recently discovered that circular knowledge flows enhance eco-innovation by linking the upstream derivation of knowledge with its downstream application (Al-Akash et al., 2024). In the framework of AIAKC, the intuitive identification of sustainability opportunities is data-driven intelligence where CKEs offer collaborative infrastructure to integrate intelligence into regenerative design, resource optimization and closed-loop innovation (Almagharbeh et al., 2025; Awad et al., 2025; Awad, 2024). Moreover, CKEs ascribe the traditional knowledge and adaptability in its use to inclusivity, as they permit different actors to contest and co-design scalable solutions for sustainability (Dziubaniuk et al., 2024; Aldabousi et al., 2024). CKEs transform AI-derived insights into hands-on strategy at scale, paving pathways towards enduring innovation, resolving the challenge of enduring technological capability whilst requiring a systems-level transformation. After these studies, the following hypothesis was formulated.

H13: CKE mediates the relationship between AIAKC and SI.

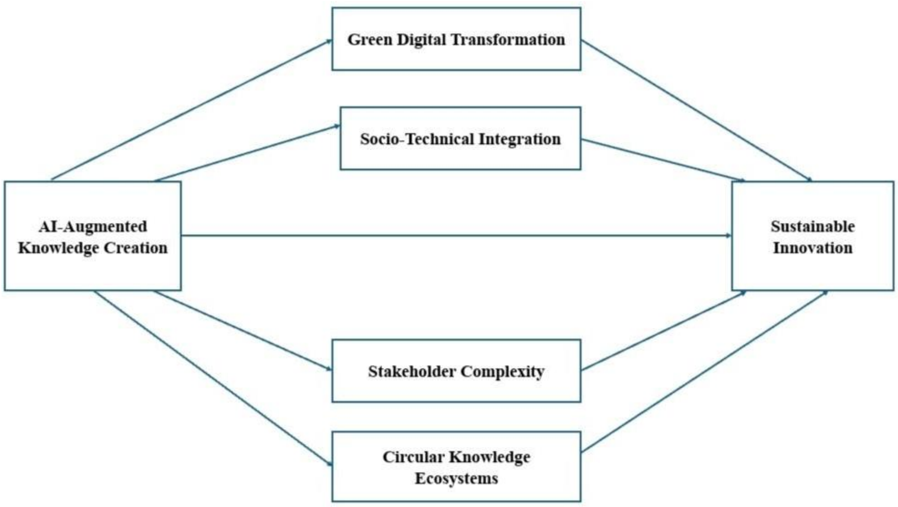

Figure 1: Conceptual Framework

METHODOLOGY

Research Model

A conceptual model developed in this study illustrates the intricate interplay of AIAKC and SI. The essence of the model views AIAKC as a primary enabling force that drives SI, operationalized by four central mediating constructs: GDT, STI, SC, and CKE. These mediators capture the multilevel processes of integration of AI capabilities into organizational knowledge systems that result in practices of innovation for sustainable development. Informed by the KBV, STS Theory, and Stakeholder Theory, the model has a systems perspective towards the relations, technology, and institutions shaping sustainability transitions. While existing literature tends to focus on AI and green transformation in contextual silos, empirical work that integrates these elements into one cohesive model, especially in the context of emerging economies such as Pakistan, is limited. In this regard, the study fills the gap by rigorously testing a comprehensive model that integrates technological intelligence, environmental responsibility, and stakeholder alignment.

Information Gathering

To relatively test the proposed model along with its respective hypotheses, the study utilized a quantitative cross-sectional research design along with a survey-based approach. Information was gathered from participants belonging to AI-intensive industries in Pakistan, such as manufacturing, fintech, renewable energy, logistics and ICT-based companies. These sectors were chosen deliberately because of their participation in AI-enhanced project work and innovation related to sustainability. The information was collected from participants from January to March 2025 using digital and physical means. Respondents were targeted using a non-probability convenience sampling method. Focus was given to respondents with first-hand knowledge of the organization's sustainability framework, such as IT managers, mid-senior-level managers, innovation officers, and sustainability practitioners. To enhance credibility, respondents were screened to ensure they held at least two years of industry work and one year in AI-related work. A total of 265 responses were collected. After removing entries that were deemed incomplete or invalid, a total of 233 responses were deemed suitable for statistical analysis. T**able 1** summarizes the respondent's profile.

The sample size surpasses the benchmarks for PLS-SEM based on a specific minimum requirement of 10 times the number of indicators per construct (Hair et al., 2019). Given the model's 21 measurement indicators and several pathways, the sample size retained is adequate for ensuring statistical power as well as model stability. PLS-SEM was selected as the primary analysis technique because of its strengths on numerous fronts, especially on complex multi-pathway models, as well as the theory-driven nature of the analysis, which is, at times, exploratory in nature (Alam et al., 2023; Awad & Alharthi, 2025; Awad, 2025). Analyses were performed using SmartPLS 4.0 which permits the concurrent estimation of measurement and structural models alongside evaluation of model reliability, validity, the significance of paths, and other critical indicators. The demographic assessment revealed a balanced profile of respondents with 57% males and 43% females from all four provinces of Pakistan, which aids in the generalizability of the results. The ethics of research were followed by ensuring anonymity of the respondents and receiving consent prior to engaging them in the study.

Common Method Bias

Considering the nature of the study in which the independent and dependent variables were captured from the same respondents using a structured questionnaire, it became imperative to mitigate concerns around common method bias (CMB). Following Podsakoff et al. (2003), the method variance assessment for this study utilized Harman's single-factor test. An exploratory factor analysis with principal component extraction was conducted on all measurement items in an unrotated format. The first factor extracted was 34.876% of variance, which is well below the conservative benchmark of 50%, suggesting that CMB is not a significant concern for the validity of the findings. In addition, some procedural design artifacts, such as anonymity, randomization of item presentation, and distinct psychological item usage, were employed to mitigate the biases. These biases distort perception of the actual relationships among AIAKC, GDT, STI, SC, and CKE which are not artifacts of the measurement context. With these measures, the trustworthiness and accuracy of the findings are bolstered even further.

Research Instrument's Development

Due to driven motivations towards developing this thesis, a carefully tailored research aid was designed through questionnaires, which included contextually relevant and pertinent AI-enabled sustainability practices within the adaptation landscape for the industry of Pakistan, by utilizing existing peer-reviewed validated measurement scales. The survey questionnaire was organized into two fundamental sections. Section one captured the sample demographic profile and organizational information such as age, gender, level of education, occupational position, tenure in AI initiatives, and type of industry in which he/she worked. These criteria ensured contextual control as well as guaranteed that the participants were adequately familiar with relevant technological and sustainability processes. In regard to the study's six core constructs, these are AIAKC, GDT, STI, SC, CKE, SI. All constructs were measured utilizing multi-item scales from knowledge management, organizational sustainability, digital transformation, and stakeholder theory. The items underwent stringent modifications to account for the industrial and cultural setting of Pakistan. A five-point Likert scale was used for every item, with 1 denoting 'strongly disagree' and 5 'strongly agree,' which enabled measuring the participant's perceptions and experiences proportional to their actual views. The constructs developed were in accordance with and based on past literature. For example, AIAKC items were taken from Alam et al. (2024) and Aivazidou et al. (2025). Items used to measure GDT were taken from Jourabchi Amirkhizi et al. (2025) and Johnson et al. (2022). STI items were adapted from Zhu et al. (2022) and were modified by subsequent studies, including Zhang et al. (2023). SC measurement items were collected from Wautelet & Rouget (2025) and later empirical work by Van der Linde (2024). CKE was measured using indicators from Ahmadov et al. (2023) and Almagharbeh et al. (2025). The outcome variable, SI, was measured relying on Anderson et al. (2024) and Block et al. (2023), who provided scales based on their prior results. Significant pilot testing was implemented to ensure focus group scale clarity and reliability, as well as verify content validity, using 20 industry respondents prior to the main data collection stage. The final questionnaire version integrated industry feedback to improve wording precision alongside contextual relevance throughout diverse situational scenarios.

DATA ANALYSIS AND RESULTS

Reliability and Validity

To evaluate the internal consistency of the constructs, the authors measured "Cronbach's alpha" and "Composite Reliability" (CR). Hair et al. (2019) indicates that factor loadings of 0.70 are ideal, although if the model as a whole is functioning well, values above 0.60 are acceptable. Based on this rule, all items loading below 0.60 were purged. All constructs in the study were found to have alpha and CR values greater than the benchmark of 0.70, thus confirming satisfactory reliability. In addition, the average variance extracted (AVE) values were greater than 0.50 (the benchmark), thus confirming adequate convergent validity. The lack of multicollinearity was also confirmed, as all VIF numbers reported were lower than 5. Table 2 summarizes the item loadings, reliability, and validity of all constructs. Discriminant validity was tested via the Fornell and Larcker criterion (Table 3) and the Heterotrait-Monotrait (HTMT) ratio (Table 4). As described by Alam et al. (2023), if all HTMT values are below the 0.85 cut-off, there are no issues with discriminant validity.

Table 1: Respondents' Profile (n = 233)

Demographic Characteristics	**Category**	**Frequency**	**Percentage**
Gender	Male	141	60.5%
	Female	92	39.5%

Age	20-30 years	61	26.2%
	31-40 years	94	40.2%
	41-50 years	56	24.0%
	Above 50 years	22	9.4%
Educational Background	Bachelors	74	31.4%
	Master’s	109	46.8%
	PhD	34	14.6%
	Others	16	6.9%
Professional Role	Manager/Team lead	97	41.6%
	Executive Officer	82	35.2%
	Consultant/Advisor	31	13.3%
	Other	23	9.9%
Years of Experience	Less than 3 years	49	21.0%
	3-6 years	88	37.8%
	7-10 years	65	27.9%
	More than 10 years	31	13.3%
Industry Type	Manufacturing	66	28.3%
	IT	57	24.5%
	Energy & Utilities	41	17.6%
	Banking /Finance	32	13.7%
	Service (Education, Healthcare)	37	15.9%

Table 2. Item, Loadings, Reliability and Validity

Constructs	**Item**	**Loading**	**Alpha**	**CR**	**AVE**	**VIF**
AI-Augmented Knowledge Creation	AIAKC1	0.812	0.874	0.925	0.637	2.124
	AIAKC2	0.798				2.011
	AIAKC3	0.826				2.178
	AIAKC4	0.831				1.987
	AIAKC5	0.784				1.654
	AIAKC6	0.845				2.213
Green Digital Transformation	GDT1	0.744	0.791	0.861	0.610	1.488
	GDT2	0.766				1.374

	GDT3	0.803				1.596
	GDT4	0.821				1.472
Socio-Technical Integration	STI1	0.781	0.807	0.872	0.630	1.559
	STI2	0.797				1.688
	STI3	0.815				1.724
	STI4	0.775				1.582
Stakeholder Complexity	SC1	0.765	0.779	0.854	0.593	1.737
	SC2	0.783				1.669
	SC3	0.811				1.511
	SC4	0.743				1.612
Circular Knowledge Ecosystems	CKE1	0.732	0.758	0.832	0.558	1.459
	CKE2	0.777				1.502
	CKE3	0.795				1.644
	CKE4	0.729				1.561
Sustainable Innovation	SI1	0.756	0.839	0.893	0.582	1.643
	SI2	0.811				1.562
	SI3	0.734				1.774
	SI4	0.798				1.489
	SI5	0.776				1.364
	SI6	0.729				1.517

Table 3. Discriminant Validity

Constructs	**AI-Augmented Knowledge Creation**	**Green Digital Transformation**	**Circular Knowledge Ecosystems**	**Socio-Technical Integration**	**Stakeholder Complexity**	**Sustainable Innovation**
AIAKC	0.798					
GDT	0.622	0.781				
CKE	0.577	0.504	0.747			
STI	0.645	0.618	0.663	0.794		
SC	0.541	0.468	0.556	0.604	0.774	
SI	0.493	0.528	0.635	0.661	0.589	0.763

Note: *Diagonal values (bold) represent the square root of AVE. Off-diagonal values are inter-construct correlations. All constructs show adequate discriminant validity.*

Table 4. Heterotrait-Monotrait (HTMT) Ratio

Constructs	**AIAKC**	**GDT**	**CKE**	**STI**	**SC**	**SI**
AIAKC	-					
GDT	0.482	-				
CKE	0.443	0.519	-			
STI	0.574	0.641	0.713	-		
SC	0.603	0.438	0.527	0.497	-	
SI	0.493	0.682	0.561	0.613	0.532	-

Note: *All HTMT values are below the conservative threshold of 0.85, indicating strong discriminant validity among constructs.*

Structural Model

In the evaluation of the structural model, consideration of all direct hypotheses (H1–H9) yielded positive and statistically significant results, indicating strong support for the proposed relationships (refer to Table 5). Each path was significant, supporting the claim that AIAKC has a bearing on SI and its components. The R^2 values within the model, from 0.263 to 0.648 indicated that the dependent variable's levels of explanatory power ranged from moderate to robust, which is consistent with Hair et al. (2019) and Alzaareer et al. (2024). Alongside, Q^2 values, which represent the predictability of relevance, also ranged between 0.148 and 0.385, illustrating reasonable predictive relevance for the model.

Table 5. Direct relationships (Hypotheses H1–H9)

Hypotheses	**Beta**		**T-value**	**P-Value**
H1: AIAKC>SI	0.589		9.240	0.000
H2: AIAKC>GDT	0.544		6.379	0.000
H3: AIAKC>STI	0.615		7.811	0.000
H4: AIAKC>SC	0.481		4.918	0.019
H5:AIAKC>CKE	0.791		12.756	0.000
H6: GDT>SI	0.264		2.549	0.012
H7: STI>SI	0.236		2.622	0.014
H8: SC>SI	0.219		2.187	0.034
H9: CKE>SI	0.193		2.418	0.021
		R^2 value		Q^2 value
GDT		0.298		0.162
STI		0.381		0.184

SC		0.263		0.148
CKE		0.539		0.385
SI		0.648		0.354

Source: Created by the author.

Mediation Analysis

The last stage of the analysis looked into the mediating impacts of GDT, STI, SC, CKE on the relationship between AIAKC and SI. All four paths confirmed partial mediation, signifying that both direct and indirect effects were present. From these results, it is apparent that AIAKC influences SI not only directly but also indirectly through each one of the mediators, demonstrating the value of these constructs for innovation achievements. In this way, all mediation hypotheses (H10–H13) were confirmed, as noted in Table 6.

Table 6. Mediation analysis

Hypotheses	Beta	T-value	P-value	Remarks
H1:AIAKC>GDT>SI	0.164	2.511	0.013	Accepted
H2: AIAKC>STI>SI	0.144	2.348	0.019	Accepted
H3: AIAKC>SC>SI	0.128	2.122	0.027	Accepted
H4: AIAKC>CKE>SI	0.146	2.284	0.011	Accepted

Source: Created by author

DISCUSSION

The purpose of this study was to find the effect AIAKC has on SI while considering the mediatory roles of GDT, STI, SC, and CKE. The results show that AIAKC affects SI significantly and positively both directly and through mediating constructs. These results support the deep impact Ais have on innovation outcomes, especially in systems with components focusing on sustainability. The evidence supports the assumption that AIAKC allows organizations to manage complexity dynamically and accelerate innovation driven by embedded green and circular capabilities. This supports the idea made by Alam et al. (2023), Anderson et al. (2024), and Awad et al. (2024) suggesting that the enabling of strategy by advanced technologies like AI can influence strategic sustainable behavior at multiple institutional levels. Additionally, these results bolster Freeman's stakeholder theory from 1984, reporting that by integrating digital intelligence with knowledge systems, businesses go beyond fulfilling stakeholder demands and innovate in ways that are socially and ecologically responsible. Consistent with other studies such as Block et al. (2023), Bonetti et al. (2024), and He et al. (2025) illustrate that AIAKC is a fundamental capability a firm has to restructure systems, alter their digital frameworks, and address sustainability-driven stakeholder concerns. The impact of AIAKC on all mediators—GDT, STI, SC, and CKE—was found to be significant, showing that with the help of AI, knowledge systems enhance the transformation of frameworks into fundamental value creation systems. Moreover, the findings suggest that the mediators themselves—GDT, STI, SC, and CKE—exert a critical positive influence on SI, confirming the assumptions about their importance as mechanisms through which AI-augmented processes catalyze sustainable results. This supports the claims of Gembali et al. (2024) and Herath Pathirannehelage et al. (2025), stating that organizations that tend to have digitally integrated systems are more agile in meeting sustainability requirements. GDT emerged as a vital channel through which AIAKC contributes to SI. Iapaolo et al.

(2024) and Aldarawsheh et al. (2024) argue that firms willing to digitize processes through Eco-efficient infrastructure, carbon tracking, and AI environmental reporting tend to sustain higher sustainable performance. STI helps in human-technical interfacing and in organizing the governance and culture of the organization, whether or not technological changes are integrated. This is in line with Jourabchi Amirkhizi et al. (2025), who emphasized the importance of socio-technical readiness in environmental innovation. The influence of SC further reveals these complex networks of cooperation among the institutional actors in support of sustainability. Just like Kim et al. (2024) and Kumar et al. (2023) discussed, the diversity of stakeholders makes it necessary for organizations to reconcile competing interests using transparent and AI-driven engagement frameworks. The results demonstrate that the application of AIAKC to stakeholder ecosystems enhances trust, co-creation, and the alignment of achieving defined sustainability objectives. Furthermore, CKE was the most dominant mediator of the model, which confirms the heightened role of circularity in innovation systems. AIAKC strengthens the loops of knowledge, nurtures design-for-disassembly, and builds open innovation environments for resource conservation and waste reduction (Smuts & Can Der Merwe, 2025; Yuen, 2023; Awad & Mahmoud, 2024; Hussain et al., 2023). This advances the argument that circular flows of knowledge, made possible through AI, can be institutionalized to transform innovation cycles and foster resilience for the ecosystem over time in the watershed. The mediation analysis verified partial mediation for all four constructs, which suggests that all four components have some degree of mediation. This affirms the proposition brought forth by stakeholder theory that an alignment between autonomous knowledge systems of the corporation and the external stakeholders contributes to a sustainable competitive edge (Smolka & Boschen, 2023; AI-Ramahi et al., 2024; EI Gareh et al., 2025). Companies that focus on building adaptive and intelligent knowledge tend to manage to change the stakeholder stance toward the firms offering enduring products and services. It facilitates the process of withstanding external pressures. Furthermore, the results contribute to the existing literature by offering a comprehensive model that merges GDT, STI, SC, and CKE as complementary mediators in the relationship of AIAKC and SI. Prior literature tended to focus on these factors in silos. This study, however, validates their holistic interdependence and synergy toward achieving sustainable results. As noted by Johnson et al. (2022), organizational sustainability is a multidimensional concept that integrates technology, innovation, and stakeholders. This study contributes to management literature as well. For example, corporations seeking to enhance SI capacity should not assume that AI-driven productivity improvements will achieve business goals. AI must be incorporated into a comprehensive strategy that encompasses green digitalization, socio-technical systems, stakeholder engagement, and circular knowledge flow frameworks. Such approaches enable firms to enhance resilience and strengthen legitimacy while fostering an environmentally responsible and stakeholder-focused innovation culture. Following Kim et al. (2024) and Kumar et al. (2023), organizations also need to charge their employees with developing an encompassing environmental awareness and green training and proliferate digital competencies throughout the entire organization. Under the guidance of AI, employee roles can not only influence the innovation culture but also advance sustainability initiatives directed at consumers. Also, improving openness, confidence, and responsibility in stakeholder relationships can strengthen the company's leadership in innovation. Finally, this research study underscores the role of AIAKC as an SI enabler. It further advances the debate by combining the concepts of green digital, socio-technical, stakeholder, and circular systems into a single model. It adds to the discourse on the effects of intelligent technologies when placed within ethical and meta-level policies designed to transform business operations by highlighting the challenges of sustainable practices in a digitalized world.

Theoretical Contributions

This research has achieved a critical theoretical advancement by examining the impact of AIAKC on SI through the mediating roles of GDT, STI, SC, and CKE in a dynamic manner. Acknowledged in isolation, these constructs have received scant attention in previous studies, particularly regarding sustainability and innovation-driven AI technology. Its primary contribution is in providing an explanation of the complex system of interactions and structures of AIAKC SI within AIAKC and SI that moves beyond traditional linear models. The findings reinforce the claim that the linkage of AI and innovation and sustainability is not a direct, simple relationship. Rather, it is mediated by socio-digital interconnections, which consist of the greening of the digital infrastructure, the control of human/tech systems' integration, complex stakeholder engagement systems, and the nurturing of replenishing knowledge loops. This adds to the emerging literature focusing on the need to build holistic models that embody the digital and sustainability transitions' complexities (e.g., Kim et al. 2024; Kumar et al. 2023; Hussain, 2025; Alghizzawi et al., 2025). This study also adds to the AI, knowledge, and sustainability literature by developing the non-Western innovation ecosystem's emerging economy frameworks, which integrate attributes of evolving regions of the world for having validated such a model. Fundamentally, the findings support the model's relevance across contexts, indicating that the possible impacts of AI on innovations that are sustainable in their scope transcend boundaries of industries and countries. Areas of research and theories in this field need to pay less attention to concepts dealing with static, input-based technological systems and more to holistic, sociotechnical systems with interdependent elements relating to ecology and environment.

Managerial Implications

Under the managerial perspective, the results have taken the form of recommendations for organizations seeking to employ AI as a tool for achieving sustainability. They should understand that AI's capacity to augment sustainable innovation will only be realized when AI is placed within an ecosystem framework that utilizes green digital architecture, socio-technical integration, stakeholder engagement, and knowledge circularity. First, spending on green digital infrastructure allows firms to decrease their environmental footprints while increasing scale on the application of AI. Secondly, socio-technical integration of human relations with technical systems ensures that innovation processes are adaptive and transformational as well as ethical. Acknowledging and dealing with the complexity of stakeholders from the regulators and partners through to the consumers and communities leads to the co-creation of value and increased legitimacy. Finally, the cultivation of circular knowledge ecosystems, where knowledge is continuously generated, shared, and regenerated across organizational borders, enhances the sustainability of long-term innovation. Embracing a reactive stance, managers ought to incorporate AI systems that work towards attaining environmental set goals such as resource optimization or emissions tracking. Fostering an internal environment whereby employees are permitted to move within and between functions and discipline systems and share ideas and knowledge freely cultivates cross-disciplinary collaboration. Sharing such efforts digitally can help reinforce the organizational identity as a proactive futuristic innovator. Additionally, concentrating on the mediators—GDT, STI, SC, and CKE—enables firms to position themselves competitively in sustainability-oriented markets. These capabilities enhance trust among stakeholders and improve innovation performance. On the other hand, businesses should consider developing advanced learning opportunities and training programs that support the workforce to AI-governed sustainability objectives. Companies can provide socio-technical interfaces and stakeholder AI integration to encourage the development of sustainable and more inclusive innovation. This is particularly important for organizations located in developing regions where there is still limited focus on AI integration and sustainability. Such firms need to define the foundational integration with circularity principles to enhance their competitiveness while addressing social and environmental needs. Thus, this study offers practical guidance on how to integrate AI features using green transformation approaches to optimize value and impact on innovation.

CONCLUSION

This analysis supports the recent consensus in scholarly literature that AIAKC has a catalytic influence in driving SI in relation to ever-evolving digital and ecological systems. The findings indicated that GDT has a pronounced impact on SI, which emphasizes the proactive nature of the adoption of environment-initiated technologies in achieving advanced outcomes of innovation. In addition, the results demonstrate the positive impact of STI, SC, and CKE on SI. These results underscore the fact that sustainable innovation is increasingly emerging from strategies that integrate diverse, complex, and intelligent systems, rather than from siloed efforts. The findings also confirmed the mediating impact of

GDT, STI, SC, and CKE regarding the relations of AIAKC and SI, indicating that AI's impact on sustainability is maximized when there is alignment with appropriate technical systems, human systems, stakeholders, and regenerative knowledge systems. These mediators make it possible for AI capabilities to be shaped into context-sensitive, value-laden, and requisite adaptive strategies for innovation. Such findings are important for many industries and regions, as they reinforce the need for a universally adaptable AI ecology-based framework aimed at sustainability. Organizations that apply AI to greening digital platforms, strategize on human capital integration with technology, manage SC, and promote circular knowledge flows will gain a competitive advantage in sustainable innovation. This study, in the end, augments the existing literature with new empirical insights and offers clear concepts that can be utilized to address ecological challenges, gain a competitive edge through AI, and foster innovation growth during the sustainability transition.

LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

The gaps outlined provide opportunities for further academic inquiry while also enhancing the practical and theoretical contributions of the study. First, the study utilizes a cross-sectional design approach, meaning perceptions and relationships within variables are captured at a single point in time. This approach offers an AI-in-mation systems perspective. AI-informed knowledge frameworks as a snapshot of imagination in its role in sustainable innovation. However, there exists the absence of looking at the "ever-changing" nature of AI technologies and knowledge ecosystems over time. Later studies should apply longitudinal or panel data methods to examine the processes through which AI-enabled knowledge formation and ecosystem integration take place across various phases of innovations and sustainability transitions. Second, the empirical analysis uses data from a particular country and industry. Even though this strengthens contextual relevance, it diminishes understanding of the applicability of the findings in other sectors or geographic regions. Future research could test this framework in other socio-economic, technological, and regulatory contexts to evaluate its applicability and resilience. Studies could also look at the differences between developed and developing countries or between digitally mature and digitally emerging industries to enrich the theoretical model. Third, the work puts most of its emphasis on the organizational-level constructs, which ignores some aspects of employee culture such as employee resistance, cultural readiness, or leadership styles that might play a role in the effectiveness of AI-enabled sustainable innovation. Further research should look into different levels of factors to include individual, team, and organization simultaneously. Fourth, while the research discusses four key mediating constructs—green digital transformation, socio-technical integration, stakeholder complexity, and circular knowledge ecosystems— it does not address other relationships that may amplify or dampen these effects. Subsequent research could explore how organizational agility, digital maturity, ethical AI governance, or regulatory conditions could mitigate or strengthen understanding boundary conditions. Fifth, it is clear from the findings that there is no dispute over the measurement models used in this study; however, the drawn-out complexity surrounding stakeholder complexity and circular knowledge ecosystems calls for additional qualitative scrutiny. Quantitative models that focus on stakeholder complexity and circular knowledge ecosystems, through in-depth case analyses, ethnography, or expert interviewing, offer rich contextual insights and undisclosed dynamics of AI innovation ecosystems. Finally, emerging technologies and trends like generative AI, decentralized autonomous organizations (DAOs), quantum computing, or AI-enabled ESG analytics provide ample opportunity for future research focus as they have a direct correlation to the fast evolution of AI technologies and their impact. The new technologies discussed might create new forms of impact in relation to knowledge augmentation or sustainability that are not currently captured within the frameworks in use. Therefore, although this paper provides a thorough preliminary examination exploring the relationship between AI, knowledge creation, and sustainability, it must be said that subsequent works should aim for broader temporal, contextual, and methodological diversity. Integrating new digitally driven organizational structures and sophisticated multi-tiered systems within the model will be critical for further developing scholarly perspective and practical insight in the context of the fast-changing landscape.

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