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Green knowledge management: A key driver of green technology innovation and sustainable performance in the construction organizations

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ABSTRACT

The primary objective of this research is to examine the effects of green knowledge management (GKM) on green technological innovation (GTI) and sustainable performance in construction firms. The study also investigates the role of artificial intelligence (AI) as a moderator of the relationship between GKM and green human capital (GHC). A survey questionnaire was used to obtain data from 309 construction firms in Pakistan, and the AMOS-24 and SPSS PROCESS macro software packages were used to test the hypotheses. The findings revealed that GKM had significant positive impacts on GTI and long-term performance. Aspects of GIC (e.g., green structural capital, green relational capital, and green human capital) were found to be significant mediators of GKM and GTI interactions and correlations between GKM and sustainable performance. Furthermore, the study showed that AI significantly influenced the relationship between GKM and GHC. The study's findings have important theoretical and practical implications for organizations and governments. The study theoretically contributes to the knowledge-based view of the firm by providing empirical evidence of the role of various GIC characteristics as mediators in the interactions between GKM, GTI, and sustainable performance. In practice, the findings suggest that firms can improve GTI and sustainable performance by investing in GKM and GIC.

Introduction

Nineteenth-century industrialism successfully lifted millions of people from poverty. However, this economic success caused environmental and resource degradation (Dahlquist, 2021). This raises the following question: Is damage to the environment necessary for economic stability? Despite the abundance of natural resources, their vulnerability to climate change jeopardizes emerging economies' economic progress. For decades, governments have been eager to set rules and standards to ensure the environmentally friendly production of goods and services (Khan, 2022; Mehmood et al., 2022; Sana, 2020). The United Nations (UN) established its Sustainable Development Goals (SDGs) to safeguard and enhance social and environmental conditions (Ham et al., 2021). In response, firms have started to recognize the importance of environmental preservation, and have been inspired to modernize their operations and management frameworks. Previous studies have shown the importance of business capabilities to the development of innovations that uncover new uses for existing goods, expertise, and resources (Hui & Khan, 2022; Khan & Khan, 2021). As innovation frequently necessitates the acquisition and application of new knowledge (Berraies & Zine El Abidine, 2019), knowledge assets are an essential resource for firms.

The capacity of an organization to gain and keep knowledge determines its failure or success (Argote et al., 2000). Firms use knowledge to boost customer satisfaction and gain a competitive edge (Dabbous & Tarhini, 2019). Knowledge management (KM) has grown in popularity in the corporate world over the last few years (Caputo et al., 2019; Kianto, 2011). It is regarded as an essential element in strategizing, developing new goods and services, and managing operations (Donate & de Pablo, 2015). An efficient KM system can boost a firm's effectiveness (Brachos et al., 2007). Moreover, given ecological challenges, vibrant firms have broadened the scope of KM and begun to integrate environmental issues into business knowledge (Sahoo et al., 2022).

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Green knowledge management (GKM) has therefore become a critical strategic asset for many firms, providing them with a competitive advantage through their capacity to accomplish the UN SDGs (Sahoo et al., 2022). Based on the concept of "green innovation," one SDG goal is to make green production processes easy for organizations (Asiaei et al., 2022). To develop sustainability practices, firms must concentrate on both technological and management innovation, and differentiate between two kinds of green innovation: green management innovation and green technology innovation (GTI). GTI integrates cutting-edge innovation with knowledge and experience to create a greener world. It helps firms to create new or improved products or operations that consume fewer raw materials and resources while enhancing ecological, financial, and industrial processes (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013).

There have been numerous studies of KM and sustainable development (Choudri et al., 2016; Farrukh et al., 2022; Guo, 2019), but less attention has been paid to GKM and how it affects GTI and organizational environmental sustainability. Furthermore, there has been limited research on the contextual elements that influence the relationship between GKM and GTI. This study addresses the knowledge gaps that prevent us from understanding how sustainable performance and GTI contribute to green practices. The knowledge-based view of the firm (KBV) regards knowledge as a crucial operational resource (Revilla et al., 2016), because an organization's diverse knowledge bases and skills are the key drivers of its long-term competitive advantage and improved organizational innovation and performance; furthermore, knowledge-based resources are often difficult to replicate and socially complicated (Chowdhury et al., 2022). Green intellectual capital (GIC) has been referred to as an important organizational resource for organizational performance and sustainability (Haldorai et al., 2022a). GIC is described as the accumulation of tangible resources or knowledge related to environmental conservation or innovation (Asiaei et al., 2022; Wang & Juo, 2021). Green human capital (GHC), green structural capital (GSC), and green relational capital (GRC) are the three major elements of GIC (Dang & Wang, 2022; Nisar et al., 2021). There have been few studies of GIC and GKM (Martín-Rubio, 2021). Due to increasing ecological concerns, it is critical to consider the combined effect of GIC and GKM on GTI and sustainable performance. Thus, based on the KBV, the goal of this study is to investigate the relationship between GKM and GIC.

This study explores the mechanism through which GIC influences organizations' sustainable performance and GTI, which is another gap in the literature. GTI consists of innovations that use improved technology, systems, and control techniques to lessen the impact of business activities on the environment (Gao et al., 2021; Liu et al., 2020). Its focus on reducing ecological damage distinguishes GTI from other types of technological innovation. GTI is built on the theoretical foundation of the KBV. According to the KBV, if firms want to maintain their credibility and access to sustainable resources, they must follow environmental laws and policies (Xie et al., 2019). Furthermore, organizations tend to apply green initiatives (e.g., GKM) to improve and sustain GTI and performance. GIC has a role in this process, and understanding the role can dispel any doubts regarding how GKM affects GTI and sustainable performance.

Several studies have examined the internal and external factors that influence GTI and sustainability. Studies of the intangible knowledge that affects green innovation have shown that GKM is a crucial component of GTI (Sahoo et al., 2022; Su et al., 2020). Unfortunately, few researchers have examined the mechanism through which GKM promotes GTI and sustainable performance. Such research must consider the varied effects of each component of GIC on GTI and sustainable performance. The current study adds to the understanding of GKM by first determining how GKM affects GTI and sustainable performance and then evaluating the mediating effect of GIC, thus elucidating the link between GKM and GTI and sustainable performance.

The scarcity of research in this arena highlights the need for more in-depth assessments of whether or how technical resources such as artificial intelligence (AI) affect the abovementioned relationships. Scientific studies have typically defined firm resources into three groups: financial, technological, and managerial (Sahoo et al., 2022). As a result, AI is defined as a firm's willingness to devote technological resources to GKM and GIC initiatives to improve GTI and sustainable performance. This is consistent with the theoretical concept of the KBV, which emphasizes that the development and management of key resources, including knowledge, assists firms in developing sustainable competitive advantages (Malik et al., 2022). AI was incorporated into the study model because it is an excellent tool for improving the efficiency and efficacy of KM and GIC projects. AI can help firms discover and manage environmental risks, develop new green goods and services, and improve their overall sustainability performance by collecting, storing, and analyzing enormous quantities of data (Sahoo et al., 2022). Other fourth-generation technical resources, such as big data, cloud computing, and robotics, can also be leveraged to improve KM and GIC. However, we contend that AI is a particularly promising technology, as it can be used to automate many of the operations involved in KM and GIC, freeing human resources to focus on more strategic activities.

Some studies have stated that developing nations are more vulnerable to environmental hazards (Adenle et al., 2015; Sharma et al., 2022), and thus using organizational resources is more challenging for firms in these countries. Therefore, another objective of this study is to investigate the applicability of the KBV research framework to the Pakistani construction industry. The construction industry is a major source of pollution that contributes to climate change. The building sector uses large amounts of natural resources and produces significant amounts of greenhouse gas (GHG) emissions (Khan & Khan, 2021; Kinnunen et al., 2022; Li et al., 2022; Mehmood et al., 2023). KM is the process of creating, sharing, and using knowledge within an organization. By enhancing efficiency, optimizing resource consumption, and introducing innovative green technologies, KM can help the construction industry to reduce its environmental impact. Employee knowledge, skills, and experience are examples of intellectual capital (IC). IC can be used to build new goods and services, improve efficiency, and generate new business models. GIC is a type of IC that focuses on environmental sustainability (Mansoor et al., 2021). GIC can be used to create new green products and services and to improve environmental performance. Effective KM would improve collaboration, learning, and innovation in the construction industry (Khan et al., 2023). An organization that values IC attracts people and distinguishes itself from other organizations. Green innovation reduces a firm's environmental impact, complies with legislation, and improves a firm's reputation. Collaboration and continual learning are facilitated via knowledge-sharing platforms. Building information modeling (BIM), the Internet of Things, and AI are examples of digital innovations that optimize resource allocation and enable data-driven decision-making that supports sustainable design and construction (Khan et al., 2023). These innovations improve project outcomes, sustainability, and construction sector competitiveness (Khan et al., 2021; Tam et al., 2004).

This study makes several important contributions to the field. First, it is the first study to investigate how AI affects the link between GKM and GIC. Second, it sheds new light on how GIC affects sustainable performance and GTI. Third, it examines the mediating role of AI in the relationship between GKM and GIC. Finally, the research is carried out in the context of the Pakistani construction sector, which is a major contributor to environmental pollution. The following research questions reflect the objectives of this study.

RQ1: What effects does GKM have on sustainable performance and GTI in the construction industry?

RQ2: How does GIC mediate the relationships between GKM and sustainable performance and between GKM and GTI?

RQ3: Does AI moderate the relationship between GKM and GIC?

The reminder of this paper is structured as follows. Section 2 presents a thorough evaluation of the literature and provides a solid theoretical foundation for the study. Section 3 describes the research methodology, including data gathering methods and analytical procedures. Section 4 discusses the study's findings, including the empirical data's support for the research hypotheses. Finally, the findings are thoroughly discussed and their implications are explored in Section 5.

Theoretical background and hypothesis development

Knowledge-based view of the firm

Traditional management theories, including the stakeholder theory, organizational theory, and the resource-based view of the firm (RBV), serve as the foundations for the KBV. Often viewed as an extension of the RBV, the KBV maintains that knowledge produced within an organization is a crucial resource for establishing a sustainable competitive advantage in dynamic environments because (a) knowledge-based sources are socially challenging to interpret and incorporate within the organization; (b) they are difficult for another firm to imitate; and (c) they are constantly evolving and being co-created within an organization (Chowdhury et al., 2022; Grant, 1996). The KBV sees itself as a knowledge producer and accelerator. The KBV framework has been widely used in the management literature and is frequently combined with the RBV and other frameworks. According to the KBV, firms are organizations that integrate knowledge, and an essential competency of a firm is the coordination of procedures for adapting the specialized knowledge of its employees to the productive functions of the organization (Al Nuaimi et al., 2021). The KBV stresses that it is the systemic and structural characteristics of firms that enable them to build the capacity to link specialized and complementary knowledge.

According to the KBV, firms require cooperation, collaboration, and adjustments in hierarchies, job designs, guidelines, and current decision-making processes as they switch focus from producing knowledge to applying knowledge. Knowledge, entrepreneurship, and innovation are well established as the cornerstones of competitiveness and economic growth (Yu et al., 2022). Recent studies have emphasized the significant impact of the integration of these factors on economic, environmental, and social goals—all of which are represented in the UN SDGs (Srisathan et al., 2023; Ribeiro-Soriano and Piñeiro-Chousa, 2021). These resources complement one another. For example, knowledge enables people and organizations to improve their innovation capacities (Berraies & El Abidine, 2019). In turn, higher innovation helps organizations to improve their performance (Brachos et al., 2007). According to Grant (1996), a critical element of firms' KM, which helps them to construct resource-based strategies, is how they gather, maintain, communicate, and use knowledge. As per the KBV, knowledge is the most important strategic resource a firm can have. Thus, this study uses the KBV framework to test the direct and indirect effects of GKM on GTI and sustainable performance via GIC. Moreover, this study considers AI an organizational resource that enhances the GKM−GIC relationship. These relationships are presented in Fig. 1.

Green knowledge management, green technological innovation, and sustainable performance

KM is frequently considered a key prerequisite for firms to thrive, endure, and grow in challenging environments (Shujahat et al., 2018). According to Revilla et al. (2016), KM separates successful organizations from failed organizations. KM is a key force driving firm growth (Chae & Bloodgood, 2006; Sahoo et al., 2022). In volatile and dynamic settings, creating and applying knowledge not only prevents failure but can also promote profit. According to the KBV, firms exist to gather knowledge and turn it into sustainable strategic advantages (Srivastava et al., 2006). This point of view emphasizes the importance of knowledge as a basic resource for enhancing performance and long-term survival (Malhotra, 2005). Knowledge is also the foundation of innovation. Consistent innovation is the result of the continuous production of knowledge.

A GTI is a new technological development that can improve environmental standards, minimize energy use and pollution emissions, and contribute to the development of a more sustainable future (Liu et al., 2020; Rehman et al., 2018). Innovation is essential for firm success and competitiveness, especially in complex environments. However, a firm's ability to innovate is influenced by the corporate environment in which it is embedded (Brachos et al., 2007). With

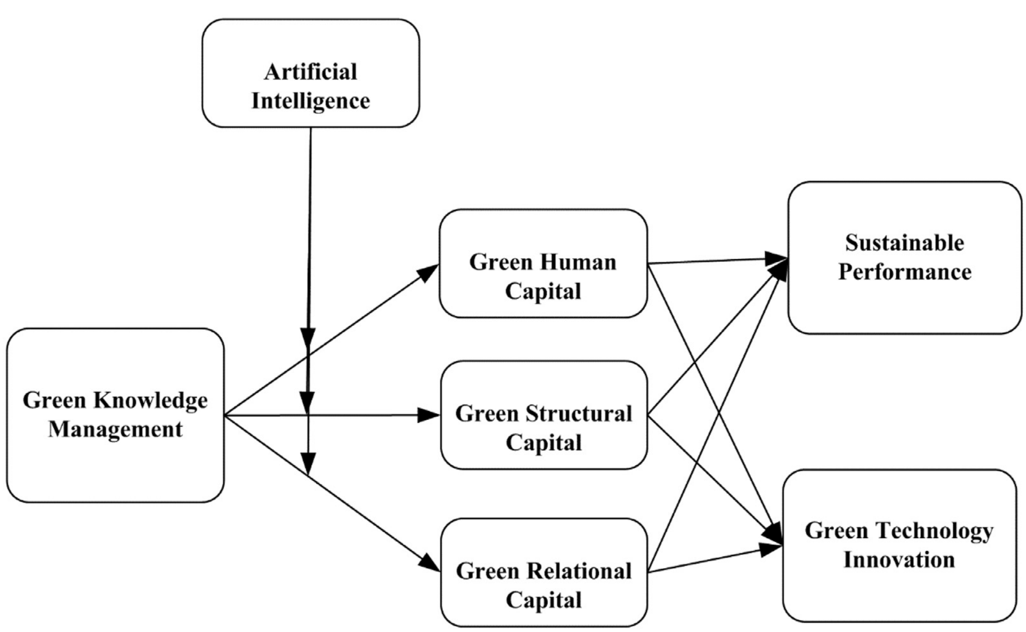

Fig. 1. Study model.

multiple stakeholders exerting immense pressure on firms to modify and adopt ethical and environmentally friendly strategies, green competency is becoming increasingly crucial for success (Chen & Hung, 2016). The increase in pollution, combined with the destruction of natural resources, has motivated many governments and communities to call for GTI on a larger scale (Al Nuaimi et al., 2021). GTI encompasses all potential green consumption and eco-process innovations that can minimize energy usage, pollution, and resource utilization. Firms' reasons for implementing GKM and GTI may fluctuate (Sahoo et al., 2022). Given that these are novel topics, scholars are only beginning to investigate these concepts, particularly in business contexts, where they are the main strategy for minimizing the negative effects of economic operations on the environment (Su et al., 2020; Yu et al., 2022). GKM consists of employees' comprehension of their surroundings and their insights into the environment, enabling shared participation in long-term development (Farrukh et al., 2022). Some recent studies of the link between KM and innovation have questioned whether there is any association between them (Kianto et al., 2017; Sahoo et al., 2022; Su et al., 2020). As a result, the relationship between GKM and GTI remains ambiguous. This motivates the following hypothesis.

H1: GKM affects GTI positively.

The link between sustainable performance and GKM is evident when viewed through the KBV's theoretical perspective (Caputo et al., 2019). GKM, which facilitates the acquisition, integration, innovation, and adoption of sustainable practices, is the scientific management of environmental knowledge within an organization (Wang et al., 2022). Organizations can improve their sustainable performance by gaining appropriate knowledge about sustainable technologies and regulations, incorporating green knowledge into organizational processes, encouraging innovation and continual improvement, and involving stakeholders (Kakar & Khan, 2020; Sahoo et al., 2022). Organizations can gain a competitive edge in the pursuit of sustainable development by employing GKM to successfully align their activities with sustainability goals, eliminate waste, reduce resource consumption, and encourage environmental stewardship (Farrukh et al., 2022). Therefore, based on these arguments, this study proposes the following hypothesis.

H2: GKM affects sustainable performance positively.

Green knowledge management and green intellectual capital

GIC is defined by Chen (2008) as the whole inventory of an organization's intangible resources, knowledge, capabilities, and interactions, among other things, related to ecological sustainability or green innovation at both the human and organizational levels. GIC is divided into three components: GHC, GSC, and GRC (Benevene et al., 2021; Delgado-Verde et al., 2014). The conceptualization of GIC arose from a widespread realization that knowledge is critical to firms' success (Giampaoli et al., 2021; Kianto et al., 2020; Rehman et al., 2021). The roles of GIC and GKM are broad, covering the full range of intellectual activity, from knowledge creation to knowledge use (Martín-Rubio, 2021; Rehman et al., 2023). GKM acknowledging the GKM−GIC relationship depicts the pool of knowledge at a certain point in time produced by knowledge flow techniques (Al-Omoush et al., 2022; Hsu & Sabherwal, 2012). The connection between IC and KM is shaped by a firm's knowledge-based perspective, which is created through seminal investigations (Grant, 1996; Malik et al., 2022; Revilla et al., 2016).

Human capital is a characteristic of individuals rather than institutions, and it can be lost when an individual quits an institution (Nahapiet & Ghoshal, 1998). Because it is crucial for firms to generate green innovation and green practices, the ecological knowledge of personnel supports the firm's compliance with external evolutionary challenges (Rehman et al., 2019; Wang & Juo, 2021). Chen (2008) introduced the concept of GHC, which he described as the total amount of employees' understanding, expertise, abilities, knowledge, mindset, intellect, creativity, engagements, etc. related to ecological sustainability or innovativeness. In contrast to human capital, structural capital is embedded in organizations and is unaffected by employee turnover. Structural capital refers to a firm's reserves of technology, programs, databases, workplace organization, and management expertise (Attar et al., 2019; Hsu & Sabherwal, 2012; Mansoor et al., 2021). Due to the rise of global green policies, firms must develop and put into practice sustainability systems if they want to seize opportunities or gain a competitive advantage. Chen (2008) developed the notion of GSC, which he described as the inventory of administrative processes, administrative obligations, knowledge systems, organizational values, workplace culture, firm reputation, inventions, copyrights, trademarks, etc., related to ecological sustainability or innovativeness within a firm.

The ties between a focal organization and its major stakeholders, including consumers, vendors, and allies, are collectively referred to as relationship capital (Mohan & Youndt, 2005; Rehman et al., 2020). Firms require the cooperation and resources of external organizations and key stakeholders to survive and grow. They are less concerned with the environment than external groups and stakeholders. Currently, firms must commit increasing resources to green applications to strengthen their ties with external organizations and stakeholders. These collaborations should be based on mutual ecological concerns. Chen (2008, p. 278) defined GRC as "the assets of a firm's interacting relations with customers, vendors, professional contacts, and allies around corporate environmental sustainability and ecological innovation." Therefore, each component of GIC is affected by an organization's GKM, as GIC is a vital organizational resource through which members of an organization can acquire expertise in managing environmental sustainability. Furthermore, KM strategies improve GHC, GSC, and GRC, while the sustainability of human capital can be used to recruit and retain IC (Asiaei et al., 2022; Yong et al., 2019). Furthermore, technological advances have significant impacts on individuals' careers and are an important part of IC, as technological advances are now empowering individuals to disburse the experience and knowledge that they accrue from fixing issues themselves or from being prior recipients of specialized services (Al-Omoush et al., 2022; Rehman et al., 2020). Based on the above discussion, this study offers the following hypotheses.

H3a: GKM affects GHC positively.

H3b: GKM affects GSC positively.

H3c: GKM affects GRC positively.

Green knowledge management, green intellectual capital, and green technological innovation

According to Lepak and Snell (2002), human capital is a critical resource for organizational innovation because employee knowledge is critical for sustaining an organization in the context of today's fast-expanding technologies. As a result, employees are likely to be motivated to apply green knowledge to GTI. Competition driven by GHC development has the potential to generate GTI (Nisar et al., 2021). GTI will be more successful in firms that have a high degree of GHC than in those with a low degree of GHC (Haldorai et al., 2022b). This study contends that GHC serves as a bridge between employee GKM and GTI, and that firms can capitalize on their GHC capacity to improve their GTI. Green innovation is a cooperative effort in a knowledge economy and does not occur at the individual level. Sustainability initiatives, according to Hart (1995), include intangible organizational innovations and practices that indicate organizations' dedication to the improvement of the natural ecosystem. The sustainability knowledge and experience required for a firm's critical collaborations with its partners should be integrated into its business processes, as this has the potential to increase joint knowledge and boost GTI outcomes. As a result, organizations with GRC can collaborate with partners to develop new green technologies, initiatives, and possibilities (Asiaei et al., 2022).

GTI might be impossible to achieve in organizations with poor green practices and a negative attitude toward the environment. An organization that absorbs environmental information at the institutional level develops a strong environmental culture, which motivates the acquisition of new ecological knowledge and promotes GTI (Asiaei et al., 2022; Liu et al., 2020). Moreover, by codifying important environmental safety knowledge and GKM into its processes, an organization can ensure that these resources are consistently communicated and promoted inside the organization and used for GTI (Sahoo et al., 2022; Wang & Juo, 2021). The KBV also emphasizes the importance of organizational knowledge-based resources in managing innovation (Grant, 1996). Thus, this study assumes that knowledge resources (specifically GKM) will enhance organizational resources (specifically GHC), which can improve GTI. Therefore, this study makes the following hypotheses.

H4a: GHC mediates the relationship between GKM and GTI.
H4b: GSC mediates the relationship between GKM and GTI.
H4c: GRC mediates the relationship between GKM and GTI.

Green knowledge management, green intellectual capital, and sustainable performance

Sustainable performance is the alignment of financial and environmental goals in the execution of fundamental corporate operations to boost returns (Dey et al., 2022). According to the KBV framework, an organization's competitive advantage is based on its strategic use of its strengths. Firms that are subject to strict environmental protections are becoming more aware of the importance of GKM, and those that use the GKM contained in the knowledge, skills, and creativity of their employees to promote ecological sustainability are more likely to adopt a green policy than their counterparts, because they understand how such strategies can improve their sustainability performance (Sami et al., 2020). As a result, GKM enables a firm to identify its intangible resources (i.e., GHC) and can assist in the successful implementation of green initiatives in uncertain environmental contexts, thus enhancing green performance. Moreover, relational capital promotes external collaboration (Nahapiet & Ghoshal, 1998; Ullah et al., 2021; Yusoff et al., 2019). Green improvements are made possible by lowering transactional, inquiry, informational, and negotiation expenses. When companies implement GRC strategies, they can generate more successful sustainability initiatives to reduce their environmental impact and engage customers interested in sustainability (Asiaei et al., 2022; Yong et al., 2022). Firms must collaborate with each other to incorporate GKM−GRC generated and disseminated learning into their processes to develop value, and to use sustainable innovative business models based on such knowledge (Haldorai et al., 2022a). Thus, GKM can enhance green performance through GRC.

Structural capital helps a firm to arrange its systems and practices so that the necessary technological expertise is developed and identified as a critical asset. Furthermore, corporate talents are a prerequisite for achieving improved long-term success. GKM, which is part of the KBV framework, assists firms in guaranteeing employee access to vital information in an environmentally and user-friendly manner (Wang et al., 2022). Under significant ecological pressure, GIC plays a crucial role in a firm's green performance (Wang & Juo, 2021). The primary goal of this study is to determine whether GIC mediates the relationship between GKM and sustainable performance. GKM refers to a firm's formal environmental knowledge (Sahoo et al., 2022). As the development of new products usually requires the use of technical knowledge by employees (Asiaei et al., 2022; Mousa & Othman, 2020), a store of information can build GSC. As a result, this study anticipates that GKM, as the environmental information developed inside a firm, will have a positive impact on the firm's sustainability performance by enabling GSC. Given the above discussion and the KBV framework, this study makes the following hypotheses.

H5a: GHC mediates the relationship between GKM and sustainable performance.

H5b: GSC mediates the relationship between GKM and sustainable performance.

H5c: GRC mediates the relationship between GKM and sustainable performance.

Moderating role of artificial intelligence

According to Nishant et al. (2020), AI is a tool that uses human intellect to increase performance in numerous sectors, and it is an emerging field in all fields seeking to boost efficiency and productivity. AI is one of the biggest technological advances of the twenty-first century, and it has already started to alter both business organizations and societies in ways that we could not have foreseen just a few decades ago. AI has become a key component of business innovation initiatives, process modernization, and disruption, and it is helping firms that have adopted a data-driven and digital environment to gain a competitive edge (Chowdhury et al., 2022). Studies have also regarded AI as an organizational resource for combating environmental issues (Dwivedi et al., 2021; Nishant et al., 2020). AI allows individuals to analyze, design, and implement comprehensive solutions to environmental destruction and environmental issues that are not influenced by reductionism or the identity of individuals and groups.

Despite numerous studies examining the impact of an organization's knowledge resources on its intangible resources (Dang & Wang, 2022; Sahoo et al., 2022; Yu et al., 2022), the role of AI in organizational sustainability and performance has received limited attention, despite the importance of AI in organizational sustainability and performance in this modern digital age. Several scientific studies have shown the importance of AI in the employee context (Li et al., 2019; Odugbesan et al., 2022; Sithambaram & Tajudeen, 2022), but these studies have not investigated the impact of AI on firm-level outcomes such as GIC or whether AI changes the relationship between GKM and GIC.

The scarcity of research in this area has led to a void in our understanding of these relationships. As a result, this study postulates that AI could either strengthen or weaken the link between GKM and GIC. First, we hypothesize that AI moderates the GKM−GHC relationship. This hypothesis is predicated on the idea that AI may be used to automate many of the processes involved in GKM, freeing up human resources to focus on more strategic operations. Employees will have more time and resources to devote to learning about and using green technologies and practices, which can lead to an increase in the level of GHC in an organization (Sahoo et al., 2022). Second, we hypothesize that AI moderates the GKM−GSC relationship. This hypothesis is based on the recognition that AI may be used to collect, store, and analyze vast volumes of data, allowing organizations to better understand their environmental impact and identify areas for improvement. This can lead to a rise in an organization's GSC, as it gains a firmer grasp of the environmental repercussions of its activities. Finally, we believe that AI will have a moderating effect on the GKM−GRC relationship. This claim is based on the premise that AI can be used to promote collaboration and communication among various stakeholders, assisting in the development and maintenance of GRC. GRC refers to an organization's knowledge and its relationships with its stakeholders, including customers, suppliers, and regulators. In general, the hypotheses that AI moderates the relationships between GKM and GHC, GKM and GSC, and GKM and GRC have some empirical evidence. More research, however, is required to confirm these associations. Accordingly, this study proposes the following hypotheses:

H6a: AI moderates the link between GKM and GHC.
H6b: AI moderates the link between GKM and GSC.
H6c: AI moderates the link between GKM and GRC.

Methodology

Sample and data collection

In 2015, the member countries of the United Nations collectively agreed to adopt the Sustainable Development Goals (SDGs), widely recognized as the 2030 Agenda. The 2030 Agenda contains 17 SDGs that must be achieved by 2030. The SDGs outlined in the 2030 Agenda are relevant to all states. Pakistan has been a trailblazer in achieving the targets of the 2030 Agenda. The Pakistani government has committed to carbon neutrality and to safeguarding the environment. The SDGs also contain important targets for the construction sector. The construction industry is one of the largest and most important drivers of economic growth and high living standards. This industry contributes significantly to Pakistan's GDP. However, it also consumes a large amount of energy and emits a high volume of GHGs. Around 40 % of energy use and GHG emissions are attributed to building design (Kinnunen et al., 2022). Improving energy efficiency and enhancing energy efficiency in buildings is thus an essential goal for combating climate change.

This study collected data using a questionnaire, which is a common method for gathering large amounts of quantitative data on industrial practices (Bahadur et al., 2020; Khan et al., 2021; Xiongfei et al., 2020). The study was carried out in Pakistan, and the data were collected from Pakistani construction firms. Firm size was not restricted in the sample selection, as the purpose was to collect data from construction firms of various types and sizes. The sample frame included the entire country of Pakistan. An Internet tool was used to collect data from the participants. The initial sample consisted of 900 randomly chosen construction firms. The firm was the analytical unit, and the participants were asked for their perspectives on how the topics under consideration operated at the firm level. The survey was circulated to potential participants who had enough knowledge to answer the questionnaire. We did not focus on sustainable development and eco-innovation executives as participants, because many small and medium-sized businesses in Pakistan do not have executives with such titles. Instead, we identified employees at each firm who we thought were reliable sources. They held various positions and responsibilities, including managing director, procurement director, site engineer, and construction manager. Most of the participants were top executive officials, and each one had to have adequate competence in and knowledge of the topics under examination. The participants were asked to provide as much information as possible while remaining anonymous. Following a couple of reminders and follow-up messages, 309 participants returned completed and legitimate survey responses, generating a 34.33 % return rate. This response rate is consistent with other empirical studies (Ali et al., 2020; Khan et al., 2023; Moin et al., 2021). Table 1 presents the sample profile, focusing on four characteristics (no. of employees, turnover, years of operations in the industry, and business type) of the participating firms.

Measures

The questionnaire survey was prepared based on the study's framework to ensure insights into each of the studied constructs. This required drawing on multiple studies to extract survey questions that characterized each of the study's major constructs. The responses used a 5-point Likert scale ranging from 1 = "strongly disagree" to 5 = "strongly agree." *GKM* was measured using a five-item scale drawn from the literature (Mao et al., 2016; Sahoo et al., 2022). A sample item is "*Employees and partners at our organization have easy access to information on best-in-class environmentally friendly practices.*" The three components of GIC were measured using a scale from Chen (2008) and recently used by Chang and Chen (2012). Sample items are as follows: for *GHC* "*The employees' competence in environmental protection in the company is better than that of its major competitors*"; for *GRC* "*The company designs its products or services in compliance with the environmental desires of its customers*"; and for *GSC* "*The management system of environmental protection in the company is better than that of its major competitors.*" AI was assessed with five items adapted from Belhadi et al. (2021) and Chen et al. (2022). One of the five sample items is "*We use AI techniques to forecast and predict environmental behavior.*" To measure sustainable performance, we used a scale adapted from Dey et al. (2022). The eight-dimensional measure for sustainable performance was separated into three components: financial performance, environmental performance, and social performance. A sample item is "*Our firm has a policy to improve its energy efficiency.*" *GTI* was measured using a scale adapted from Huang and Li (2017) and Sahoo et al. (2022). The measure consisted of five items and a sample item is "*Our organization is actively involved in the redesign and improvement of products or services in order to comply with existing environmental or regulatory requirements.*"

Data analysis and results

Test of method bias and endogeneity

By determining whether early participants' answers significantly differed from those of late participants, the possibility of non-response bias was examined (Armstrong & Overton, 1977). The analyses of construct mean yielded p-values ranging from 0.514 to 0.880. Therefore, non-response bias did not affect the study's findings. Moreover, common method bias (CMB) can affect the results if the data are collected from a single source (Podsakoff et al., 2003). By motivating the participants to respond honestly and permitting them to stay anonymous, this bias was mitigated (Podsakoff et al., 2003). The questionnaire items were meticulously crafted based on previous studies to make them as accurate as possible, as another methodological strategy to minimize CMB. With the help of a group of academics with expertise in the subject, the final composition of the questionnaire items was developed over several iterations. Five academics from the disciplines of digital technology and service businesses oversaw the gathering of survey

Table 1
Information about control variables.

Variables	N	Percentage	Variables	N	Percentage
No. of employees			Years of operations in the industry		
<200	61	19.7	<5 Years	38	12.3
500 ≤ no. < 1000	82	26.5	5 ≤ Years < 10	70	22.7
1000 ≤ no. < 2000	66	21.4	10≤ Years < 15	100	32.3
>2000	100	32.4	>15 Years	101	32.7
Annual Turnover (in millions)			Business type		
<100 PKR	49	15.8	Residential/home construction	55	17.8
100 ≤ PKR <200	73	23.6	Infrastructure construction	46	14.9
200 ≤ PKR <300	53	17.2	Commercial construction	61	19.7
300 ≤ PKR <400	81	26.2	Industrial construction	105	34.0
>400 PKR	53	17.2	Other	42	13.6

Table 2
Factors loadings, CR, and AVE, and research items.

Measures	Factor Loadings
Green Knowledge Management (CR = 0.892; AVE = 0.622; Cronbach α = 0.891)	
“Employees and partners at our organization have easy access to information on best-in-class environmentally friendly practices”.	0.788
“Our organization has procedures in place to gain knowledge about the environmental practices of our competitors, suppliers, clients, and strategic partners”.	0.804
“Our organization has structured mechanisms in place to exchange best practices across multiple disciplines of business operations”.	0.811
“Our organization develops initiatives (such as seminars, periodic meetings, and collaborative projects) that promote green information exchange across divisions/stakeholders”.	0.756
“Our organization actively engages in processes that apply knowledge to solve new challenges across organizational departments and beyond departmental boundaries”.	0.784
Artificial Intelligence (CR = 0.864; AVE = 0.560; Cronbach α = 0.863)	
“We possess the infrastructure and skilled resources to apply AI information processing system”.	0.757
“We use AI techniques to forecast and predict environmental behavior”.	0.748
“We develop statistical, self-learning, and prediction using AI techniques”.	0.816
“We use AI techniques at all levels of the operations”.	0.730
“We use AI outcomes in a shared way to inform decision-making”.	0.686
Green Human Capital (CR = 0.863; AVE = 0.559; Cronbach α = 0.861)	
“The productivity and contribution of employees concerning environmental protection in the company is better than those of its major competitors”.	0.756
“The employees’ competence of environmental protection in the company is better than that of its major competitors”.	0.796
“The products and services of environmental protection provided by the employees of the company are better than those of its major competitors”.	0.804
“The cooperative degree of teamwork pertaining to environmental protection in the company is more than that of its major competitors”.	0.758
“Managers in the company can fully support their employees to achieve the goals of environmental protection”.	0.609
Green Structural Capital (CR = 0.902; AVE = 0.608; Cronbach α = 0.902)	
The management system of environmental protection in the company is better than that of its major competitors”.	0.685
“The company’s profit earned from environmental protection activities is more than that of its major competitors”.	0.808
“The company’s ratio of environmental protection investments in R&D to its sales is more than that of its major competitors”.	0.814
“Innovations about environmental protection in the company are more than those of its major competitors”.	0.843
“Investments in environmental protection facilities in the company are more than those of its major competitors”.	0.792
“The environmental knowledge management system in the company is favorable for the accumulation and sharing of environmental management knowledge”.	0.723
Green Relational Capital (CR = 0.828; AVE = 0.616; Cronbach α = 0.829)	
“The company designs its products or services in compliance with the environmental desires of its customers”.	0.792
“The company’s cooperative relationships about environmental protection with its upstream suppliers and downstream clients are stable”.	0.822
“The company has stable and cooperative relationships about environmental protection with its strategic partners”.	0.739
Green Technology Innovation (CR = 0.899; AVE = 0.640; Cronbach α = 0.898)	
“Our organization continuously optimizes the processes by using cleaner methods or green technologies to make savings”.	0.766
“Our organization is actively involved in the redesign and improvement of products or services in order to comply with existing environmental or regulatory requirements”.	0.754
“Our organization specializes in recycling practices to ensure that end-of-life products are recovered for reuse in new product”.	0.798
“Our organization is rigorously involved in “eco-labeling” activities to make our clients conscious of our sustainable management practices”.	0.845
“The Research & Development team at our organization ensures that the current technical advancement is included in the development of new eco-initiatives”.	0.832
Sustainable Performance (CR = 0.923; AVE = 0.601; Cronbach α = 0.922)	
“Our company has an initiative to reduce, reuse, and recycle”.	0.807
“Our company has an initiative to reduce the negative environmental impact of its products”.	0.859
“Our has a policy to improve its energy efficiency”.	0.800
“Our company has competitive advantages in its sales and profit growth”.	0.712
“Our company has a competitive advantage in cost saving and efficiency”.	0.760
“Our company has a competitive advantage in its value”.	0.774
“Our company has a policy to strive to be a good corporate citizen”.	0.770
“Our company has a policy to respect business ethics”.	0.711

Note: CR = Composite reliability, AVE = Average variance extracted. All factor loadings are significant at the $p < 0.001$ level.

data. Additionally, this study operationalized the marker variable (MV), as suggested by Podsakoff et al. (2003), to further verify the influence of CMB on the data. The findings suggested that there was no significant distinction between the baseline model and the alternative model, as there was no significant difference in the chi-square values. These results established that the data were unaffected by the inclusion of the MV, and it was thus implausible that CMB affected the conceptual model’s hypothesized relationships.

We also considered the possible effects of endogeneity. For example, reverse causality between the predictors and the outcome variable, which would suggest that the dependent variable affects the independent variables, may result in endogeneity (Antonakis & House, 2014). However, this study’s theoretical model and hypotheses were based on the KBV, which refutes the notion of reverse causality. However, several researchers (Antonakis & House, 2014; Rahman et al., 2023) have determined that CMB may cause endogeneity problems. To evaluate CMB in our dataset, we used the tests outlined above and concluded that our dataset was not affect by CMB. The likelihood of reverse causality was further decreased by the survey’s use of cross-sectional data. Every component of the study variables was modified based on the literature (Hui et al., 2023; Rahman et al., 2023). Finally, to further prevent endogeneity issues, we followed the recommendation of Antonakis and House (2014) on control variables.

We ran several tests to ensure the reliability, validity, and compatibility of the variables with the core assumptions of analysis of covariance before evaluating the hypotheses. SPSS and AMOS were used to analyze the data. AMOS is a software program for testing theoretical models that uses covariance-based structural equation modeling (SEM). It is an excellent tool for testing complex interactions between latent variables. AMOS is also reasonably simple to use and interpret, making it an excellent choice for researchers new to SEM. AMOS has certain advantages over PLS (a variance-based method). PLS is a newer approach and has been applied in fewer empirical studies. Furthermore, PLS is less powerful than AMOS and can be more difficult to interpret. AMOS was chosen by the study’s authors as the most suitable approach for evaluating a complex theoretical model with several latent variables.

First, the validity and reliability of the measures were evaluated; the results are shown in Table 2. According to Hair et al. (2010), the lowest cut-offs for Cronbach’s alpha (α), composite reliability (CR),

Table 3
Descriptive statistics and correlation matrix.

Constructs	Mean	SD	GKM	AI	GHC	GSC	GRC	GTI	SP
Green Knowledge Management (GKM)	3.96	0.84	(0.79)						
Artificial Intelligence (AI)	3.79	0.73	.14*	(0.75)					
Green Human Capital (GHC)	3.54	0.83	.58***	.30**	(0.75)				
Green Structural Capital (GSC)	3.45	0.82	.40***	.12*	.65***	(0.78)			
Green Relational Capital (GRC)	3.57	0.97	.44***	.25**	.67***	.59***	(0.79)		
Green Technology Innovation (GTI)	3.51	0.82	.61***	.02	.59***	.46***	.44***	(0.80)	
Sustainable Performance (SP)	3.52	0.86	.57***	-.05	.72***	.62***	.54***	.66***	(0.77)

Note: (1) *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$, (2) Square root of AVE are shown in parentheses on the diagonal.

and average variance extracted (AVE) values are 0.70, 0.70, and 0.50, respectively. Furthermore, factor loadings should exceed 0.60 (Bagozzi & Yi, 1988). The results in Table 3 show the discriminant validity of the standardized constructs, which was confirmed by the AVE of the variables being above their squared correlation (Fornell & Larcker, 1981). Second, the variance inflation factors had a relatively low magnitude (between 1.14 and 1.21) when calculated using a different predictive model. Confirmatory factor analyses were then performed to assess the proposed model's fit. Measures such as chi-square/df < 5, CFI, IFI, TLI (above 0.90), and RMSEA (less than 0.08) (Hair et al., 2010) had values within the recommended ranges. The model fit metrics were as follows: CMIN/DF = 1.783; p = 0.00; IFI = 0.934; CFI = 0.927; TLI = 0.933; SRMR = 0.0452; RMSEA = 0.050, showing a good fit of the measurement model. As the data met all of the statistical tests for fit, we next tested the hypotheses.

Hypothesis testing

The PROCESS macro was used to test the study's hypotheses, including the posited moderated impacts (Hayes, 2017). The results confirmed the first hypothesis that *GKM* had a positive impact on *GTI* (β = 0.37, $p < 0.001$), as shown in Table 4. The outcomes also showed that *GKM* positively influenced *sustainable performance* (β = 0.39, $p < 0.001$), supporting H2. The analysis also demonstrated that *GKM* had a significant impact on *GHC* (β = 0.52, $p < 0.001$), GSC (β = 0.35, $p < 0.001$), and *GRC* (β = 0.39, $p < 0.001$), supporting H3a–H3c. We used PROCESS macro Model 4 to test the hypothesized mediating relationships. The findings presented in Table 4 showed that *GHC* (β = 0.17, CI = [0.085, 0.273]), *GSC* (β = 0.09, CI = [0.039, 0.162]), and *GRC* (β = 0.08, CI = [0.032, 0.144]), mediated the link between *GKM* and *GTI*, which confirmed H4a–H4c. Similarly, H5a–H5c were supported, as *GHC* (β = 0.27, CI = [0.171, 0.369]), *GSC* (β = 0.15, CI = [0.077, 0.238]), and *GRC* (β = 0.12, CI = [0.060, 0.193]), mediated the relationship between *GKM* and *sustainable performance*, and all of the relationships were significant.

This study used PROCESS Model 1 to assess the moderating effect of *AI* on the relationship between *GKM* and *GIC*. For *GHC* (β = 0.19, $p < 0.01$) the interaction term (*GKM***AI*) was significant and positive; however, for *GSC* and *GRC* the interaction term was not significant (Table 4). To evaluate the interaction effects, we tested the moderating effect of *GKM* and *AI* at one standard deviation above and below the mean. As shown in Fig. 2, when *AI* was higher, the effect of *GKM* on *GHC* was stronger, which is consistent with H6a. Thus, H6a was supported, but H6b and H6c were rejected. Finally, we tested the impact of the control variables on our outcome variables, and found that none of them were significant.

Although we did not hypothesize a moderated mediation link, we used the PROCESS macro to test whether *AI* moderated the association between *GKM* and *GTI* and *sustainable performance* via *GHC*. According to the index of moderated mediation, the indirect influence of *GKM* on *GTI* (conditional indirect effects = .06, 95 %CI = [0.029, 0.104]) and *sustainable performance* (conditional indirect effects = .10, 95 %CI = [0.049, 0.167]) via GHC were statistically significant.

Discussion

By applying a KBV framework, this study tested the relationships between GKM, GTI, and sustainable performance through GIC. This study also tested the moderating effects of AI on the relationships between GKM and the three GIC components. To the best of our knowledge, this study is among the first to test these relationships in the construction industry, which is famous for its destructive impacts

Table 4
Hypotheses testing results.

	Estimates	S.E.	LLCI	ULCI
Green Knowledge Management (GKM) → Green Technology Innovation (GTI, H1)	.37***	.052	.263	.468
Green Knowledge Management → Sustainable Performance (SP, H2)	.39***	.052	.299	.503
Green Knowledge Management → Green Human Capital (GHC, H3a)	.52***	.049	.417	.608
Green Knowledge Management → Green Structural Capital (GSC, H3b)	.35***	.052	.237	.443
Green Knowledge Management → Green Relational Capital (GRC, H3c)	.39***	.061	.328	.569
Mediating effects				
GKM → GHC→GTI (H4a)	.17***	.048	.085	.273
GKM → GSC→GTI (H4b)	.09**	.032	.039	.162
GKM → GRC→GTI (H4c)	.08**	.029	.032	.144
GKM → GHC→SP (H5a)	.27***	.050	.171	.369
GKM → GSC→SP (H5b)	.15***	.041	.077	.238
GKM → GRC→SP (H5c)	.12*	.034	.060	.193
Moderating effects				
Artificial Intelligence (AI) → GHC	.28***	.055	.175	.392
Artificial Intelligence → GSC	.09	.062	-.034	.211
Artificial Intelligence → GRC	.24**	.072	.102	.384
GKM x AI → GHC (H6a)	.19**	.043	.106	.275
GKM x AI → GSC (H6b)	.06	.048	-.034	.157
GKM x AI → GRC (H6c)	.11	.056	-.002	.218

Note: N = 309. LLCI = lower level of the 95 % confidence interval; ULCI = upper level of the 95 % confidence interval; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

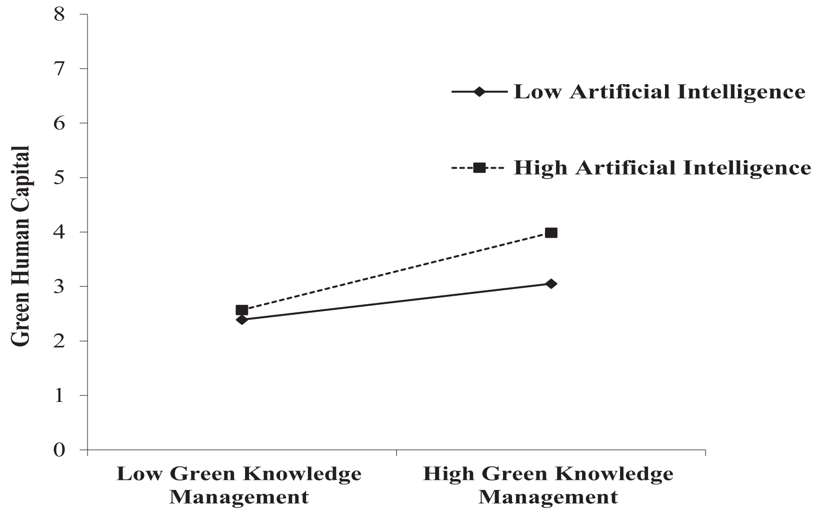

Fig. 2. Moderating influence of AI on the GKM-GHC relationship.

on the environment (Kinnunen et al., 2022). The findings add to the literature on KM, innovation, sustainability, and AI by using an experimental approach to produce insights with theoretical and practical implications and to identify new areas for future research. The findings are described below.

This investigation of GKM's effects on GTI and sustainable performance yielded noteworthy findings. The empirical evidence is consistent with studies that found organizational resources to be positively associated with green innovation (Su et al., 2020; Wang et al., 2022). Sahoo et al. (2022) found a similar connection between GKM and green innovation and green performance. This important conclusion suggests that Pakistani construction firms can improve their GTI and sustainable performance by applying GKM. The findings demonstrate that GKM has a positive influence on GIC. The results corroborate previous research showing a similar positive association (Martín-Rubio, 2021; Sahoo et al., 2022), and are consistent with the idea that firms can improve their GIC if they have resources and GKM competencies.

Furthermore, the study's mediation analysis shows that GIC mediates the relationships between GKM and both GTI and sustainable performance. These findings are consistent with previous studies investigating similar relationships (Asiaei et al., 2022; Martín-Rubio, 2021). Finally, this study reveals that the moderating effects of AI strengthen the positive impact of GKM on GHC, but that these moderating effects are not significant in the case of GKM−GSC and GKM−GRC relationships. Although no other study has tested the moderating impacts of AI in these relationships, we postulate that AI's significant moderating effect on GHC is due to employees' use of technical resources to improve their knowledge (Chowdhury et al., 2022). Studies have shown that employee−AI collaboration can help employees to attain new knowledge and increase their contribution to organizational performance and sustainability knowledge (Chowdhury et al., 2022; Nishant et al., 2020).

Theoretical contributions

This work makes several theoretical contributions. First, by examining the relationships between GKM, GTI, and sustainable performance, this research contributes to the literature on the KBV, which suggests that organizations can improve their performance and competitiveness by using their intangible resources (Grant, 1996). This implies that firms with a strong focus on GKM can improve their GTI capacities and thus improve performance. This conclusion supports earlier studies that found (Sahoo et al., 2022) that GKM functions as a predecessor to GTI and sustainability, thus boosting sustainable performance. Second, by testing the direct effects of GKM on GIC, this study contributes to the KM and IC literature. Our findings contradict earlier studies that found that IC affects KM (Hsu & Sabherwal, 2012). Our different findings could be related to our study's construction industry setting, as recent and updated knowledge may help construction firms to improve their intangible resources (Zhang & Sun, 2020).

Third, we found that GIC is a crucial mediator between GKM, GTI, and sustainable performance, which has received little attention. In the context of developing countries, the analysis of GIC as a mediator is a new theoretical perspective, because only a small number of studies have examined how GKM influences GTI and sustainable performance (Al-Hakimi et al., 2022). GIC acts as a catalyst for cutting-edge goods and operations that help companies to "go green." It is an essential component in emerging economies like Pakistan, where ineffective manufacturing techniques and waste disposal have seriously harmed the environment. Our results suggest that Pakistani firms are using GIC to effectively improve their sustainable performance and innovation. By demonstrating that GIC remains a significant component of sustainable performance, our research adds to the KBV literature by considering the perspective of emerging nations.

Finally, this study sheds light on AI's function as a moderating factor in the GKM and GHC cycles. This is one of the most important contributions of this study to the AI literature. This finding highlights AI's important role in assisting organizations to use their technical resources to enhance the capabilities of their intangible resources. However, firms cannot depend solely on AI, they must also use GKM to improve cooperation and coordination between employees (Rahman et al., 2023).

Practical contributions

Our results also have important practical implications for policymakers interested in organizations' GTI and sustainable performance, as many firms are attempting to become greener (Dey et al., 2022). Given the different structures of industrial activities in different sectors and the absence of expertise in sustainability policies, the results of this study suggest that managers should develop cutting-edge information technology infrastructures to support the efficiency of GKM and GTI (Sahoo et al., 2022). This investment will be more effective if it corresponds to the firm's strategic "mission and vision" statements, which are explicitly related to a linked management approach. Managers in engineering contexts should consider managing all of the firm's technology resources to ensure compatibility. Empirical examples show that the implementation of GKM, GTI, and sustainability initiatives is particularly beneficial to firms seeking to promote a cooperative green mindset across varied organizational teams and their ecosystem of business allies (Asiaei et al., 2022; Xie et al., 2019).

Management, practitioners, and legislators concentrate on the essential and sufficient conditions for firms to achieve financial advantages. In addition to this aim, firms may seek to increase their annual revenues to stay in the market. Researchers have developed several models illustrating the internal qualities, competencies, or resources required to support positive financial performance (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013; Huselid, 1995). However, firms must focus on more than just improving their financial success. They must also be accountable for maintaining a sustainable and safe environment. As a result, they must take additional precautions to protect the environment and decrease the impact of corporate operations. These goals may lead to changes in their talent base, knowledge, or intangible resources (Algarni et al., 2022).

The findings of this study provide insights for construction firms seeking to enhance their sustainable performance and GTI. The main findings contribute to a better understanding of the most essential strategic dimensions of GIC for achieving improved sustainable performance and GTI. They demonstrate that GKM and GIC are the key drivers of sustainability performance and GTI, and thus organizations should invest in these resources to promote GTI and firm performance. This entails taking strong measures to boost eco-innovation, such as establishing processes that enable the creation of innovative environmental inventions and investing in cutting-edge environmental solutions. Similarly, emphasizing green marketing techniques can boost construction firms' performance (Kinnunen et al., 2022). Consequently, for the managers of construction firms, green marketing is an important part of green strategies, in particular frequent market research on sustainable development, telling customers about the latest sustainable products and solutions, and investing in the firm's eco-friendly reputation.

Finally, the findings supporting the importance of AI as a GHC moderator indicate the relevance of AI to an organization. An organization must have a clear plan to fulfill its goals, which can only be achieved when its management deploys the required human, technical, and monetary resources. Many problems can be solved by integrating AI so that it enhances organizational sustainability and process performance. Staff training is necessary for the incorporation of AI into an organization to ensure the sustainability of projects that require interactions between humans and machines (Chowdhury et al., 2022). To maintain stakeholders' confidence, institutions should also create an "internal and external control tower" to address ethical concerns relating to privacy, to hire and retain staff who are technologically savvy, and to modify training materials to accommodate the growing necessity of GTI achieved through AI–human interactions (Rahman et al., 2023).

Conclusion

This study focused on the relationships between GKM and green GTI and sustainable performance in the construction industry and the role of AI in these relationships. The results showed that GKM positively impacts GTI and sustainable performance. Both the relationship between GKM and GTI and the relationship between GKM and sustainable performance are mediated by GIC. The GKM–GHC relationship is significantly affected by AI. The study has implications for firms seeking to use GKM and GIC to improve their GTI and sustainable performance.

Limitations and implications for future research

Despite the significance of the findings, it is necessary to evaluate them in light of the study's constraints. First, as only 309 participants were included in the sample, it is difficult to extrapolate the findings. The results may be extended in future research by increasing the sample size, changing the sector and country examined, and employing a time-wave or longitudinal design. Second, in the context of Pakistan, this study solely examined the moderating impact of AI on the effect of GKM on GHC. Future studies could focus on additional elements that may influence this relationship, like the type of leadership or organizational support in a firm. Third, although this study included some control variables and controlled for their impacts on outcome variables, future studies could test the direct impacts of control variables such as gender and industry type on the outcome variables. Finally, future studies should consider how much environmental dynamism—that is, the rate at which an environment changes—affects the postulated relationships between GKM and GTI and sustainable performance.

Ethical approval

All procedures performed in studies involving human participants were following the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval was taken from the ethical committee of participating organizations.

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Availability of data and materials

Data for this study can be attained on the request from the corresponding author.

Declaration of Competing Interest

All authors of this study declare that they have no conflict of interest. None of the authors is financially or non-financially involved with the organizations being studied in this article.

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