Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X Volume 4, Issue 4, 2026

IMPLEMENTATION OF GREEN CONSTRUCTION TECHNOLOGIES AND PROJECT SUSTAINABILITY PERFORMANCE: THE MODERATING ROLE OF REGULATORY ENFORCEMENT IN THE PAKISTANI CONSTRUCTION INDUSTRY

Dr. Mohammed Usman Ali Khan[*1], Buland Iqbal[2], Mujeeb Ahmed[3], Hafiz Ul Asa[4]

[*1]*Lecturer, Electrical, UET Peshawar*
[2]*Student, Department of Civil Engineering, UET Mardan*
[3]*Graduate Civil Engineer (Currently Working as a Sub-Engineer In Public Health Engineering And Rural Development Department, Gos), Civil Engineering, Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah (Quest Larkana Campus, Previously Known as Qucest Larkana)*
[4]*Student, Department of Institute of Civil Engineering, SPbPU Russia*

[*1]musmank@gmail.com, [2]iqbalbuland628@gmail.com, [4]khanjadoon419@gmail.com

DOI: https://doi.org/10.5281/zenodo.19974307

Keywords
Green Construction Technologies; Project Sustainability Performance; Regulatory Enforcement; Construction Industry; Sustainability; Pakistan

Article History
Received: 03 March 2026
Accepted: 13 April 2026
Published: 30 April 2026

Corresponding Author: *
Dr. Mohammed Usman Ali Khan

Abstract

The construction industry is a major contributor to environmental degradation, necessitating the adoption of sustainable practices such as green construction technologies (GCTs). This study examined the impact of GCT implementation on project sustainability performance (PSP) in the Pakistani construction industry, with a particular focus on the moderating role of regulatory enforcement. A quantitative research design was employed, and data were collected from 278 construction professionals using a structured questionnaire. The data were analyzed using Structural Equation Modeling (SEM) to test the proposed relationships. The findings revealed that green construction technologies have a significant positive effect on project sustainability performance, indicating that the adoption of environmentally friendly materials, energy-efficient systems, and digital tools enhances environmental, economic, and social outcomes. Regulatory enforcement was also found to have a direct positive impact on sustainability performance. Furthermore, the study confirmed that regulatory enforcement significantly moderates the relationship between GCTs and PSP, such that the positive effect of green technologies is stronger under conditions of strict enforcement. The study concludes that the successful achievement of sustainability in construction projects requires not only the adoption of green technologies but also strong regulatory frameworks to ensure their effective implementation. The findings provide valuable insights for policymakers, industry practitioners, and researchers, highlighting the importance of integrating technological and institutional approaches to promote sustainable construction practices in developing economies.

INTRODUCTION

The construction industry is widely recognized as one of the most resource-intensive and environmentally impactful sectors, contributing significantly to global energy consumption, material depletion, and greenhouse gas emissions. As sustainability concerns intensify, the transition toward environmentally responsible construction practices has become a strategic priority for both developed and developing economies. In this context, green construction technologies (GCTs)—including

energy-efficient materials, low-carbon design approaches, and digital innovations—have emerged as critical enablers for achieving sustainable development goals within the built environment (Lu et al., 2024). These technologies not only mitigate environmental degradation but also enhance economic efficiency and social well-being, thereby supporting the triple bottom line of sustainability.

Project sustainability performance (PSP), encompassing environmental, economic, and social dimensions, has increasingly become a key metric for evaluating the success of construction projects. Recent empirical studies highlight that the adoption of green practices—such as eco-design, green procurement, and sustainable resource management—positively influences organizational and project-level sustainability outcomes (Chaudhary et al., 2024). In particular, within the construction sector, the integration of green supply chain management and innovative technologies has demonstrated a strong association with improved sustainability performance, emphasizing the need for holistic and systemic implementation strategies (Abdur Rahman et al., 2023). Moreover, advancements such as Building Information Modeling (BIM) and digital construction tools have further strengthened the capacity of firms to optimize resource utilization and enhance sustainability outcomes across project lifecycles (Zhang et al., 2023).

Despite the growing recognition of GCTs, their adoption in developing countries, particularly in Pakistan, remains relatively limited due to financial constraints, lack of technical expertise, and institutional barriers. The Pakistani construction industry, while playing a pivotal role in national economic development, faces significant challenges in aligning with sustainable construction practices. Studies indicate that large-scale implementation of green building technologies in Pakistan requires supportive policy frameworks, stakeholder awareness, and technological readiness (Hussain et al., 2024). Furthermore, the sector's sustainability transition is often hindered by weak enforcement of environmental regulations and inconsistent governance mechanisms.

Regulatory enforcement has been identified as a crucial institutional factor influencing the adoption and effectiveness of green construction initiatives. Strong environmental regulations and their effective enforcement can compel construction firms to integrate sustainable practices into their operations, thereby enhancing overall sustainability performance. Conversely, weak regulatory frameworks may undermine the potential benefits of green technologies, limiting their impact on project outcomes. Empirical evidence suggests that environmental regulation not only directly influences green productivity but also interacts with organizational capabilities to shape sustainability performance in the construction industry (Yang & Fang, 2024). Additionally, governance mechanisms play a vital role in ensuring compliance and fostering accountability, which are essential for achieving long-term sustainability objectives (El-Hakim & AbouZeid, 2024).

Given this backdrop, there is a growing need to examine the interplay between the implementation of green construction technologies and project sustainability performance, particularly in the context of developing economies like Pakistan. More importantly, understanding the moderating role of regulatory enforcement can provide deeper insights into how institutional pressures influence the effectiveness of green initiatives. While prior studies have explored the direct relationships between green practices and sustainability outcomes, limited attention has been paid to the conditional effects of regulatory mechanisms within the Pakistani construction sector.

Therefore, this study aims to bridge this gap by investigating the impact of green construction technologies on project sustainability performance, while examining the moderating role of regulatory enforcement in the Pakistani construction industry. The findings are expected to contribute to both theoretical and practical domains by offering a comprehensive framework that integrates technological, organizational, and institutional perspectives to promote sustainable construction practices.

Problem Statement

The construction industry plays a pivotal role in economic development; however, it is simultaneously one of the largest contributors to

environmental degradation, excessive resource consumption, and carbon emissions. In response to growing environmental concerns, green construction technologies (GCTs) have been introduced as effective mechanisms to promote sustainability across construction project lifecycles. These technologies—ranging from energy-efficient materials to digital tools such as Building Information Modeling (BIM)—are designed to minimize environmental impact while enhancing economic and social outcomes. Despite their proven benefits, the implementation of GCTs remains inconsistent and limited, particularly in developing countries such as Pakistan.

In the Pakistani construction industry, several structural and institutional barriers hinder the widespread adoption of green technologies. These include high initial investment costs, lack of technical expertise, insufficient awareness among stakeholders, and weak integration of sustainability principles into project management practices. Consequently, project sustainability performance (PSP)—which encompasses environmental protection, cost efficiency, and social well-being—remains suboptimal. While prior studies have established a positive relationship between green practices and sustainability outcomes, the extent to which GCT implementation translates into improved PSP within the Pakistani context is still underexplored.

Moreover, regulatory enforcement emerges as a critical yet often overlooked factor influencing the effectiveness of green construction initiatives. Although environmental regulations and policies exist in Pakistan, their enforcement is frequently inconsistent, weak, or inadequately monitored. This lack of stringent regulatory oversight reduces the pressure on construction firms to adopt sustainable practices, thereby limiting the potential impact of GCTs on project performance. Conversely, strong regulatory enforcement can act as a catalyst, ensuring compliance, promoting accountability, and enhancing the effectiveness of green technology implementation.

Despite the recognized importance of regulatory frameworks, there is a significant research gap in understanding how regulatory enforcement moderates the relationship between GCT implementation and project sustainability performance. Existing literature has largely focused on direct effects, neglecting the conditional role of institutional forces in shaping sustainability outcomes. Therefore, there is a need for a comprehensive investigation that integrates technological adoption with regulatory dynamics to better understand their combined impact on sustainability performance in the Pakistani construction sector.

Research Questions

1. To what extent does the implementation of green construction technologies influence project sustainability performance in the Pakistani construction industry?
2. How does regulatory enforcement affect project sustainability performance?
3. Does regulatory enforcement moderate the relationship between green construction technologies and project sustainability performance?
4. What are the key barriers and drivers influencing the adoption of green construction technologies in Pakistan?

Research Objectives

General Objective:

To examine the impact of green construction technologies on project sustainability performance, with a particular focus on the moderating role of regulatory enforcement in the Pakistani construction industry.

Specific Objectives:

1. To evaluate the extent of green construction technology implementation in the Pakistani construction sector.
2. To assess the impact of green construction technologies on project sustainability performance.
3. To analyze the role of regulatory enforcement in influencing sustainability performance.
4. To investigate the moderating effect of regulatory enforcement on the relationship between GCT implementation and project sustainability performance.
5. To identify key challenges and enabling factors affecting the adoption of green construction technologies in Pakistan.

Significance of the Study

This study holds substantial theoretical, practical, and policy relevance by addressing a critical gap in sustainable construction research within the context of developing economies, particularly Pakistan. Theoretically, it contributes to the existing body of knowledge by integrating green construction technologies (GCTs), project sustainability performance (PSP), and regulatory enforcement into a single analytical framework. By examining the moderating role of regulatory enforcement, the study extends current sustainability and construction management literature, which has largely focused on direct relationships while overlooking the conditional influence of institutional factors.

From a practical perspective, the findings of this study are expected to provide valuable insights for construction firms, project managers, and industry practitioners. Understanding how GCT implementation influences sustainability performance—and how this relationship is strengthened or weakened by regulatory enforcement—can support more informed decision-making. The study will help industry stakeholders identify effective strategies for adopting green technologies, optimizing resource utilization, and improving overall project outcomes in terms of environmental, economic, and social performance.

In terms of policy implications, this research offers evidence-based guidance for government authorities, regulatory bodies, and policymakers in Pakistan. By highlighting the importance of strong and consistent regulatory enforcement, the study underscores the need for improved governance mechanisms, stricter compliance systems, and supportive policy frameworks to encourage sustainable construction practices. It can assist in designing more effective regulations and enforcement strategies that not only promote the adoption of green technologies but also ensure their successful implementation.

Furthermore, the study provides a contextual contribution by focusing specifically on the Pakistani construction industry, where sustainability adoption remains limited despite increasing environmental concerns. The insights generated will be particularly useful for bridging the gap between policy formulation and practical implementation in developing countries with similar institutional and economic conditions.

Overall, this research advances the understanding of how technological and institutional factors interact to influence sustainability performance, offering a comprehensive foundation for future academic research and practical advancements in green construction.

Literature Review

The growing global emphasis on sustainability has significantly influenced the construction industry, prompting a shift toward environmentally responsible practices and technologies. Green construction technologies (GCTs) have emerged as a central concept in sustainable construction, encompassing a wide range of practices such as energy-efficient building materials, waste minimization techniques, renewable energy integration, and advanced digital tools. These technologies aim to reduce the environmental footprint of construction activities while enhancing economic efficiency and social value.

Green Construction Technologies (GCTs)

Green construction technologies refer to innovative methods, materials, and processes that improve environmental performance throughout a project's lifecycle. Recent studies emphasize that GCTs not only contribute to reduced carbon emissions and resource conservation but also improve operational efficiency and long-term cost savings. For instance, the adoption of digital technologies such as Building Information Modeling (BIM) has been shown to enhance design accuracy, minimize material waste, and facilitate better decision-making (Zhang et al., 2023). Similarly, green materials and energy-efficient systems play a critical role in achieving sustainable construction outcomes (Lu et al., 2024).

However, the adoption of GCTs is often constrained by several barriers, particularly in developing countries. High initial investment costs, lack of technical expertise, limited awareness, and resistance to change are commonly cited challenges. In the Pakistani context, these barriers are further compounded by inadequate infrastructure and limited institutional support, which hinder the large-

scale implementation of green technologies (Hussain et al., 2024).

Project Sustainability Performance (PSP)

Project sustainability performance (PSP) is a multidimensional construct that evaluates the success of construction projects based on environmental, economic, and social criteria. Environmental performance includes factors such as energy efficiency, waste reduction, and emission control; economic performance focuses on cost-effectiveness and lifecycle value; while social performance addresses stakeholder well-being, safety, and community impact.

Empirical research indicates a strong positive relationship between the adoption of green practices and improved sustainability performance. Green supply chain management, eco-friendly design, and sustainable resource utilization have been found to significantly enhance project outcomes (Chaudhary et al., 2024). Additionally, integrating sustainability principles into project management practices leads to improved efficiency, reduced operational costs, and enhanced organizational reputation (Abdur Rahman et al., 2023). These findings highlight the importance of embedding sustainability into all phases of construction projects.

Regulatory Enforcement and Sustainability

Regulatory enforcement plays a critical role in shaping organizational behavior and promoting sustainable practices in the construction industry. Environmental regulations are designed to ensure compliance with sustainability standards; however, their effectiveness largely depends on the strength and consistency of enforcement mechanisms. Strong regulatory enforcement can compel firms to adopt green technologies and adhere to environmental standards, thereby improving sustainability performance.

Studies suggest that regulatory pressure significantly influences green innovation and environmental performance in construction firms (Yang & Fang, 2024). Moreover, governance frameworks that emphasize accountability and compliance are essential for achieving long-term sustainability goals (El-Hakim & AbouZeid, 2024). In contrast, weak enforcement reduces the incentive for firms to invest in sustainable practices, limiting the overall effectiveness of green initiatives.

Moderating Role of Regulatory Enforcement

While the direct effects of GCTs on sustainability performance are well-documented, recent literature has begun to explore the moderating role of institutional factors such as regulatory enforcement. A moderating variable influences the strength or direction of the relationship between independent and dependent variables. In this context, regulatory enforcement can either strengthen or weaken the impact of GCT implementation on project sustainability performance.

Emerging evidence suggests that in environments with strong regulatory frameworks, the positive effects of green technologies on sustainability outcomes are significantly enhanced. For example, firms operating under strict environmental regulations are more likely to fully implement green practices and achieve higher sustainability performance (Zhu et al., 2024). Similarly, institutional pressures, including regulatory enforcement, have been found to reinforce the relationship between technological innovation and project performance (Zhang et al., 2023).

However, in countries like Pakistan, where regulatory enforcement is often inconsistent, the moderating effect may be weaker or more complex. This highlights the need for empirical investigation to better understand how regulatory mechanisms interact with technological adoption in influencing sustainability outcomes.

Research Gap

Despite the growing body of literature on green construction and sustainability, several gaps remain. First, most studies have focused on developed economies, with limited research addressing the unique challenges faced by developing countries such as Pakistan. Second, while the direct relationship between GCTs and sustainability performance is well-established, the moderating role of regulatory enforcement has not been sufficiently explored. Third, there is a lack of integrated frameworks that simultaneously consider technological, organizational, and institutional factors in explaining sustainability performance.

Therefore, this study seeks to address these gaps by examining the impact of green construction technologies on project sustainability performance while incorporating regulatory enforcement as a moderating variable within the Pakistani construction industry context. This integrated approach is expected to provide a more comprehensive understanding of the factors influencing sustainable construction practices.

Underpinning Theory: Institutional Theory

This study is underpinned by Institutional Theory, which provides a robust framework for understanding how external pressures influence organizational behavior and decision-making, particularly in the adoption of sustainable practices. Institutional Theory posits that organizations operate within a broader social and regulatory environment that shapes their structures, strategies, and practices through various forms of pressure, including regulatory, normative, and mimetic forces.

According to this theory, organizations tend to conform to institutional expectations to gain legitimacy, stability, and access to resources. In the context of the construction industry, regulatory bodies, industry standards, and societal expectations act as institutional forces that encourage firms to adopt environmentally sustainable practices, including green construction technologies (GCTs). These pressures are typically categorized into three dimensions: coercive pressures (arising from laws and regulations), normative pressures (stemming from professional standards and industry norms), and mimetic pressures (resulting from the imitation of successful competitors).

Within this study, regulatory enforcement represents a form of coercive institutional pressure. Strong and consistent enforcement of environmental regulations compels construction firms to adopt green technologies and comply with sustainability standards. Conversely, weak enforcement may reduce the urgency for firms to implement such practices, even if regulations formally exist. Therefore, regulatory enforcement not only directly influences organizational behavior but also shapes the effectiveness of GCT implementation.

Institutional Theory is particularly relevant for explaining the moderating role of regulatory enforcement in the relationship between GCTs and project sustainability performance (PSP). It suggests that the impact of green technologies on sustainability outcomes is contingent upon the strength of institutional pressures. In environments with strict regulatory enforcement, organizations are more likely to fully implement and effectively utilize GCTs, leading to improved sustainability performance. In contrast, in weak institutional settings, the same technologies may not yield optimal results due to lack of compliance and accountability.

Furthermore, in developing countries such as Pakistan, institutional environments are often characterized by regulatory inconsistencies and enforcement gaps. Institutional Theory helps explain why the adoption and effectiveness of sustainable practices vary significantly across contexts. It highlights the importance of governance mechanisms and regulatory frameworks in shaping organizational commitment to sustainability.

In summary, Institutional Theory provides a comprehensive lens for analyzing how regulatory enforcement influences the relationship between green construction technologies and project sustainability performance. It supports the study's argument that technological adoption alone is insufficient; rather, its success is largely dependent on the strength of institutional forces that govern and guide organizational behavior.

Hypotheses Development

H1: Green construction technologies have a positive and significant effect on project sustainability performance.

H2: Regulatory enforcement has a positive and significant effect on project sustainability performance.

H3: Regulatory enforcement positively moderates the relationship between green construction technologies and project sustainability performance, such that the relationship is stronger under higher levels of regulatory enforcement.

Methodology

This study adopted a quantitative research approach to examine the relationship between

green construction technologies (GCTs) and project sustainability performance (PSP), as well as the moderating role of regulatory enforcement in the Pakistani construction industry. A cross-sectional survey design was employed, as data were collected at a single point in time from industry professionals involved in construction projects.

Population and Sampling

The target population of the study consisted of construction industry professionals in Pakistan, including project managers, site engineers, consultants, contractors, and sustainability experts working in both public and private sector organizations. These respondents were selected due to their direct involvement in construction project planning, execution, and sustainability-related decision-making.

A non-probability purposive sampling technique was used to ensure that only individuals with relevant knowledge and experience in construction and sustainability practices were included. Based on commonly accepted guidelines for structural equation modeling and survey-based research, a sample size of approximately 250–350 respondents was considered adequate. Accordingly, a total of 320 questionnaires were distributed, out of which 278 valid and usable responses were received and analyzed, yielding a satisfactory response rate.

Data Collection

Primary data were collected using a structured questionnaire designed based on previously validated measurement scales from existing literature. The questionnaire comprised multiple sections, including demographic information and constructs related to GCTs, PSP, and regulatory enforcement. All items were measured using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

The survey was administered through both online platforms and physical distribution, ensuring broader accessibility and participation across different regions of Pakistan.

Data Analysis

The collected data were analyzed using Structural Equation Modeling (SEM) to test the hypothesized relationships. Prior to hypothesis testing, data screening and preliminary analyses were conducted, including checks for missing values, outliers, and normality. Reliability and validity of the measurement model were assessed using Cronbach's alpha, composite reliability, and average variance extracted (AVE).

To examine the moderating effect of regulatory enforcement, an interaction term was created and tested within the structural model. The significance of path coefficients, along with model fit indices, was used to evaluate the proposed hypotheses.

Ethical Considerations

The study ensured that all ethical standards were maintained throughout the research process. Participation was voluntary, and respondents were assured of confidentiality and anonymity. Informed consent was obtained prior to data collection, and the data were used solely for academic purposes.

Data Analysis and Results

The data analysis was conducted using a structured and systematic approach to ensure reliability, validity, and robustness of the findings. The analysis included descriptive statistics, measurement model assessment, and structural model evaluation using Structural Equation Modeling (SEM).

Descriptive Statistics

The demographic profile of respondents provided insight into the composition of the sample.

Table 1: Respondent Demographics

Category	Frequency	Percentage (%)
Gender (Male)	214	77.0%
Gender (Female)	64	23.0%
Experience (1–5 yrs)	82	29.5%
Experience (6–10 yrs)	109	39.2%
Experience (>10 yrs)	87	31.3%
Role (Engineers)	121	43.5%
Role (Managers)	94	33.8%
Role (Others)	63	22.7%

The majority of respondents were male (77%), reflecting the gender distribution typical of the construction industry. A significant proportion (70.5%) had more than five years of experience, indicating that the data were collected from knowledgeable professionals. Engineers and managers constituted the largest groups, ensuring that responses were informed by practical and strategic perspectives.

Measurement Model Assessment

Reliability Analysis

Table 2: Reliability Statistics

Construct	Cronbach's Alpha	Composite Reliability (CR)
Green Construction Technologies	0.89	0.91
Regulatory Enforcement	0.87	0.90
Sustainability Performance	0.91	0.93

All constructs exhibited Cronbach's alpha values above 0.70, indicating strong internal consistency. Composite reliability values also exceeded the recommended threshold of 0.70, confirming that the measurement items reliably represented their respective constructs.

Convergent Validity

Table 3: Convergent Validity

Construct	AVE	Factor Loadings Range
Green Construction Technologies	0.63	0.72 – 0.88
Regulatory Enforcement	0.60	0.70 – 0.85
Sustainability Performance	0.66	0.74 – 0.89

The Average Variance Extracted (AVE) values for all constructs exceeded 0.50, confirming adequate convergent validity. Factor loadings were above the acceptable threshold (0.70), indicating that items strongly contributed to their respective constructs.

Discriminant Validity

Table 4: Discriminant Validity (Fornell-Larcker Criterion)

Construct	GCT	RE	PSP
GCT	0.79		
RE	0.52	0.77	
PSP	0.64	0.58	0.81

(Diagonal values represent square root of AVE)

The square root of AVE for each construct was greater than its correlations with other constructs, confirming discriminant validity. This indicated that each construct was distinct and measured a unique concept.

Structural Model Assessment

Hypothesis Testing

Table 5: Structural Model Results

Hypothesis	Relationship	Beta (β)	t-value	p-value	Result
H1	GCT → PSP	0.45	7.82	0.000	Supported
H2	RE → PSP	0.31	5.64	0.000	Supported
H3	GCT × RE → PSP (Moderation)	0.18	3.27	0.001	Supported

- **H1:** Green construction technologies had a significant positive effect on project sustainability performance ($\beta = 0.45$, $p < 0.001$). This indicates that increased adoption of green technologies leads to improved environmental, economic, and social outcomes in construction projects.
- **H2:** Regulatory enforcement also showed a significant positive impact on sustainability performance ($\beta = 0.31$, $p < 0.001$). This suggests that stronger enforcement of environmental regulations enhances project sustainability outcomes.
- **H3:** The interaction effect between GCT and regulatory enforcement was significant ($\beta = 0.18$, $p < 0.01$), confirming the moderating role of regulatory enforcement. This implies that the positive effect of green construction technologies on sustainability performance becomes stronger when regulatory enforcement is high.

Model Fit Indices

Table 6: Model Fit Statistics

Fit Index	Value	Recommended Threshold
CFI	0.94	≥ 0.90
TLI	0.92	≥ 0.90
RMSEA	0.05	≤ 0.08
SRMR	0.04	≤ 0.08

All model fit indices met the recommended thresholds, indicating a good fit between the proposed model and the observed data. This confirms that the model was appropriate for explaining the relationships among the variables.

The findings of this study demonstrated that green construction technologies significantly enhance project sustainability performance, supporting the argument that technological innovation is a key driver of sustainable construction. Additionally, regulatory enforcement not only directly improves sustainability outcomes but also strengthens the effectiveness of green technologies.

The moderating effect highlights the importance of institutional mechanisms in ensuring that technological adoption translates into meaningful sustainability improvements. In the context of Pakistan, this suggests that without strong enforcement of regulations, the potential benefits of green construction technologies may not be fully realized.

Overall, the results provide strong empirical support for the integrated role of technology and regulatory frameworks in achieving sustainable construction outcomes.

Discussion

The findings of this study provide strong empirical support for the positive role of green construction technologies (GCTs) in enhancing project sustainability performance (PSP) within the Pakistani construction industry. The significant relationship between GCTs and PSP indicates that the adoption of environmentally friendly materials, energy-efficient systems, and digital tools contributes meaningfully to improved environmental, economic, and social outcomes. These results are consistent with prior research, reinforcing the argument that technological innovation is a critical driver of sustainable construction practices. The findings suggest that firms integrating green technologies into project design and execution are better positioned to optimize resource utilization, reduce waste, and achieve long-term cost efficiencies.

Furthermore, the study confirms that regulatory enforcement plays a crucial role in influencing sustainability outcomes. The positive and significant effect of regulatory enforcement on PSP demonstrates that strong governance mechanisms and compliance frameworks encourage construction firms to adhere to environmental standards. This aligns with institutional perspectives, where coercive pressures such as laws and regulations shape organizational behavior. In the Pakistani context, where regulatory frameworks exist but enforcement is often inconsistent, the findings highlight the importance of strengthening monitoring and compliance systems to ensure effective implementation of sustainability practices.

Most importantly, the moderating effect of regulatory enforcement provides deeper insights into the interaction between technological and institutional factors. The results indicate that the effectiveness of GCTs in improving sustainability performance is significantly enhanced under conditions of strong regulatory enforcement. This suggests that technology alone is insufficient; rather, its impact depends on the institutional environment in which it is implemented. In weak regulatory settings, firms may adopt green technologies superficially or fail to fully utilize them, limiting their potential benefits. Conversely, strict enforcement compels firms to effectively implement and integrate these technologies, resulting in superior sustainability outcomes.

Conclusion

This study concluded that green construction technologies are a vital determinant of project sustainability performance in the Pakistani construction industry. The results demonstrated that the adoption of GCTs significantly improves environmental, economic, and social dimensions of project performance. Additionally, regulatory enforcement was found to be a key factor that not only directly influences sustainability outcomes but also strengthens the relationship between GCTs and PSP.

The study established that an integrated approach—combining technological innovation with strong institutional enforcement—is essential for achieving sustainable construction. Without effective regulatory mechanisms, the potential of green technologies may remain underutilized. Therefore, both technological advancement and regulatory rigor are necessary to drive meaningful progress toward sustainability in the construction sector.

Implications

The findings of this study carry important implications for theory, practice, and policy. Theoretically, the study contributes to the literature by integrating technological and institutional perspectives into a unified framework, thereby extending the application of institutional theory in the context of sustainable construction. It highlights the conditional role of regulatory enforcement, offering a more nuanced understanding of how sustainability outcomes are achieved.

From a practical standpoint, the study provides valuable insights for construction firms and project managers. It emphasizes the need to move beyond mere adoption of green technologies toward their effective implementation. Firms should invest in training, capacity building, and technological infrastructure to fully leverage the benefits of GCTs. Moreover, aligning organizational strategies with regulatory requirements can enhance both compliance and performance outcomes.

In terms of policy, the study underscores the importance of strengthening regulatory frameworks and enforcement mechanisms in Pakistan. Policymakers should focus on developing clear guidelines, improving monitoring systems, and ensuring strict compliance with environmental standards. Incentives for adopting green technologies, along with penalties for non-compliance, can further encourage sustainable practices in the construction industry.

Future Directions

Future research can build upon this study by exploring additional variables that may influence sustainability performance, such as organizational culture, leadership commitment, and stakeholder engagement. Longitudinal studies could provide deeper insights into the long-term impact of green construction technologies and regulatory enforcement on project outcomes. Additionally, comparative studies across different regions or countries could help identify contextual differences and best practices in sustainable construction.

Further research may also investigate the role of emerging technologies, such as artificial intelligence, smart construction systems, and circular economy practices, in enhancing sustainability performance. Expanding the scope to include small and medium-sized enterprises (SMEs) could provide a more comprehensive understanding of industry-wide adoption challenges and opportunities.

Recommendations

Based on the findings, several recommendations are proposed. First, construction firms should prioritize the adoption and effective implementation of green construction technologies by investing in modern tools, sustainable materials, and workforce training. Second, regulatory authorities should strengthen enforcement mechanisms by improving inspection systems, increasing transparency, and ensuring accountability. Third, collaboration between government agencies, industry stakeholders, and academic institutions should be encouraged to promote knowledge sharing and innovation in sustainable construction practices.

Additionally, financial incentives such as tax benefits, subsidies, and green financing options should be introduced to reduce the cost burden associated with adopting green technologies. Awareness campaigns and capacity-building programs can further enhance understanding and acceptance of sustainable practices among industry professionals.

Limitations

Despite its contributions, this study has certain limitations. First, the use of a cross-sectional research design limits the ability to establish causal relationships over time. Second, the reliance on self-reported data may introduce response bias, as participants may have provided socially desirable answers. Third, the study focused solely on the Pakistani construction industry, which may limit the generalizability of the findings to other contexts.

Furthermore, the use of purposive sampling may restrict the representativeness of the sample, although it ensured that respondents possessed relevant expertise. Future studies can address these limitations by employing longitudinal designs, using objective performance measures, and expanding the scope to include multiple countries or regions.

Overall, this study provides a comprehensive understanding of how green construction technologies and regulatory enforcement interact to influence project sustainability performance, offering valuable insights for advancing sustainable development in the construction industry.

References

Abdur Rahman, A., Ali, S. M., & Jehangir, M. (2023). The moderating effect of environmental collaboration on green supply chain management practices and sustainability performance in the construction industry. *Research Journal of Social Sciences and Economics Review, 4*(2), 161–173.

Chaudhary, M. A. I., Syeda, A., & Balsalobre-Lorente, D. (2024). Green supply chain management practices and sustainable organizational performance in construction organizations. *Cogent Business & Management, 11*(1), Article 2331990.

Darko, A., & Chan, A. P. C. (2017). Critical analysis of green building research trend in construction journals. *Habitat International, 57*, 53–63.

El-Hakim, Y., & AbouZeid, M. N. (2024). Towards mitigating climate change negative impact: The role of regulations and governance in the construction industry. *Sustainability, 16*(16), 6822.

Hussain, B., Naqvi, S. A. A., & Balsalobre-Lorente, D. (2024). Green building technology and sustainable construction: The case of Pakistan. *Journal of Urban Technology, 32*(1), 77–101.

Hwang, B. G., & Tan, J. S. (2012). Green building project management: Obstacles and solutions for sustainable development. *Sustainable Development, 20*(5), 335–349.

Lu, W., Lou, J., Ababio, B. K., Zhong, R. Y., Bao, Z., Li, X., & Xue, F. (2024). Digital technologies for construction sustainability: Status quo, challenges, and future prospects. *npj Materials Sustainability, 2*(1), 10.

Maqbool, R., Sudong, Y., Manzoor, N., & Rashid, Y. (2017). The impact of emotional intelligence, project managers' competencies, and transformational leadership on project success: An empirical perspective. *Project Management Journal, 48*(3), 58–75.

Ofori, G. (2015). Nature of the construction industry, its needs and its development: A review of four decades of research. *Journal of Construction in Developing Countries, 20*(2), 115–135.

Shen, L. Y., Tam, V. W. Y., Tam, L., & Ji, Y. (2010). Project feasibility study: The key to successful implementation of sustainable and socially responsible construction management practice. *Journal of Cleaner Production, 18*(3), 254–259.

Testa, F., Iraldo, F., & Frey, M. (2011). The effect of environmental regulation on firms' competitive performance: The case of the building and construction sector in some EU regions. *Journal of Environmental Management, 92*(9), 2136–2144.

Yang, Z., & Fang, H. (2024). How do environmental regulation and decentralization interactively affect the green productivity of the construction industry? *Sustainability, 16*(14), 6138.

Zhang, M., Fan, L., Liu, Y., Zhang, S., & Zeng, D. (2023). The relationship between BIM application and project sustainability performance: Mediation role of green innovation and moderating role of institutional pressures. *Buildings, 13*(12), 3126.

Zhou, X., Zhang, Y., & Wang, J. (2024). Green construction practices and economic performance: The mediating role of social and environmental performance. *Integrated Environmental Assessment and Management, 20*(5), 1396–1408.

Zhu, Q., Sarkis, J., & Lai, K. H. (2013). Institutional-based antecedents and performance outcomes of internal and external green supply chain management practices. *Journal of Purchasing and Supply Management, 19*(2), 106–117.

Zhu, Q., Zou, F., & Zhang, X. (2024). Development of green business strategies through green dynamic capabilities and environmental regulation: Evidence from the construction sector. *Journal of Cleaner Production, 438*, 140826.

Zuo, J., & Zhao, Z. Y. (2014). Green building research–current status and future agenda: A review. *Renewable and Sustainable Energy Reviews, 30*, 271–281.