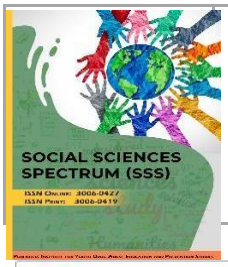

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Green Engineering Projects: The Role of Project Management in Achieving Environmental Sustainability Goals

Shahid Ali[1] Dr. Aurangzeb Zulfiqar Khan[2] Zeeshan Haider[3]

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Abstract

The growing emphasis on environmental sustainability in engineering projects has highlighted the need to embed sustainability principles within project management. Nonetheless, there exist deficits of robust empirical data that can have the direct impact of those practices on environmental outcomes. This paper examines how some of the most important aspects of green engineering projects, which include project planning, risk management, and stakeholder engagement, affect environmental sustainability performance in green engineering projects. A quantitative, cross-sectional survey was designed, where 250 respondents (project managers, engineers, and environmental professionals) participated in the survey. The analysis was conducted using descriptive statistics, reliability test, correlation, and multiple regression analysis. The findings show that the three factors significantly and positively affect sustainability performance, with stakeholder engagement being the most significant predictor. The results also show that properly organized project management leads to improved environmental performance, such as increased energy efficiency, less waste, and improved emission control. In general, this research provides empirical data that can support the incorporation of sustainability values into the engineering project management practices.

Keywords: Environmental Sustainability, Green Engineering Projects, Project Planning, Risk Management, Stakeholder Engagement.

[1] QA/QC Manager -Middle East Region, Department: Department of Management Sciences, Abasyn University, Peshawar, Pakistan.

[2] Professor, Department of Project Management & Supply Chain Management, Bahria Business School, Bahria University, Islamabad, Pakistan.

[3] Research Scholar, Master by Research in Logistics and Supply Chain Management
University of Greater Manchester, United Kingdom (UK).

Corresponding Author: Dr. Aurangzeb Zulfiqar Khan, **Correspondence through:** auranzebzulfiqarkhan@gmail.com

Introduction

An integrated approach that balances environmental, social, and economic purposes is increasingly becoming a common practice in engineering practice (Ullah et al., 2023; Wang et al., 2023). In the context of this transition, green engineering initiatives will focus on maximizing the utilization of resources, reducing waste, and promoting low-carbon solutions through the entire project life cycle (Nwaogbe et al., 2025; Liu et al., 2022). In these regards, project management practices (PMP) can be viewed as crucial as they can offer systematic approaches to planning, executing, and monitoring sustainability-related aims (Phung et al., 2022; Abdelkhalik and Azmy, 2022). According to recent studies, PMPs are highly promising to increase sustainability performance (SP) and improve environmental outcomes in construction and infrastructure projects (Shah et al., 2023; Fajri and Sujana, 2025). In addition, the growing use of sustainable PMPs is also indicative of an increased effort to incorporate environmental factors in determination methods, thus enhancing project efficiency and increasing environmental responsibility (Leo et al., 2024; Rosengart et al., 2023).

However, maintainability is rising interest, the majority of engineering projects fail to achieve their environmental goals fully (Hwang & Tan, 2012). Although projects are inclined to claim that they are in line with sustainability, there are always loopholes in the implementation since there is ineffective integration of the environmental goals in the core processes of managing the project. Sustainability is usually taken as an accidental factor and not a project requirement. Empirically, it has been established that bad environmental performance is an outcome of bad coordination of sustainability tools in planning and risk management (Stanitsas et al., 2021).

Please consider including examples of specific project categories or types where many initiatives have been undertaken. Name a few examples of prominent and successful initiatives that were completed sometime back and demonstrated sustainability.

The literature has focused mostly on the conceptual arguments regarding sustainability in engineering projects, yet there is a lack of empirical evidence on how PMPs directly affect environmental performance (Orieno et al., 2024). In particular, the specific roles of project planning (PP), risk management (RM) and stakeholder engagement (SE) in sustainability success have not been researched in detail (Shah et al., 2023). Recent studies also highlight the need to have more powerful data-driven analysis between PMPs and SP (Soares et al., 2024).

Research Objectives

1. To determine the impact of project management practices on environmental sustainability outcomes in green engineering projects.
2. To determine the relationship between key project management factors and sustainability performance.
3. To determine the effectiveness of project management strategies in achieving environmental sustainability goals in engineering projects.

The work is a contribution to the academic literature as it examines the relationship between PMPs and the environmental sustainability outcomes (Malik et al., 2023). It gives useful information to engineers and project managers to enhance the design and construction of green engineering projects (Dushing & Shete, 2024; Zhu, 2024). Moreover, it assists policymakers in creating more enduring sustainability guidelines and governance systems of engineering projects (Opoku et al.,

2024). The investigation also contributes to the knowledge of data-driven sustainability reporting and its contribution to enhancing project transparency and SP (Ahmed et al., 2023).

Literature Review

Green Engineering and Environmental Sustainability (ES)

Green engineering (GE) is considered as the strategy and practice of engineering techniques that reduce the ecological impact and maximize the efficiency of resources and the sustainability. Recent literature underlined the fact that green engineering projects were created to minimize emissions, optimize energy consumption, and introduce environmentally friendly materials throughout the project lifecycles (Rosengart et al., 2023; Alghamdi, 2025). The three pillars that were traditionally considered to be ES are 3Ps (Planet, Profit, People) is gaining more and more popularity in engineering practice (Liu et al., 2022; Ahmed et al., 2024; Bukhari et al., 2025). Sustainability in the field of engineering was mainly linked to the minimization of carbon emissions, decrease in waste, and efficient utilization of natural resources (Nwaogbe et al., 2025; Onubia et al., 2019). The principles of green engineering always insisted on the life-cycle thinking and eco-efficiency as the key elements of sustainable development (Ahmed, 2023).

Project Management in Engineering Projects

Project management is important for ensuring that the engineering projects are carried out within the scope, time, cost and sustainability constraints. Formal project management systems offer formalized methods of planning, implementing and controlling of the engineering processes. According to recent studies, the implementation of sustainability goals into engineering processes was impossible without the use of project management practices (Shah et al., 2023; Mickovski et al., 2022). Change in this project lifecycle, including beginning, coordination, enforcement, tracking, and conclusion, was instigated more and more to incorporate environmental performance indicators. The incorporation of sustainability in these stages guaranteed that the environmental issues were taken into account at the very beginning of the project creation (Borg et al., 2020; Sabini & Alderman, 2021; Sarmad et al., 2018). It was noted that projects that had well-organized management systems had positive environmental outcomes as compared to unorganized approaches.

Project Management Practices and Sustainability

Project Planning

Planning of projects was viewed as a preliminary step towards incorporating sustainability in engineering projects. It entailed the allocation of resources, scheduling, budgeting and the environmental impact assessment. Research has discovered that sustainable project planning enhanced decision-making by ensuring that the use of resources was aligned to its environmental goals (Yu et al., 2023; Stanitsas et al., 2021; Khan et al., 2020). Effective scheduling minimized the amount of waste supplies and minimized the use of energy during the implementation of the project. Planning frameworks were becoming more environmentally friendly to make them adhere to the sustainability targets (Sukla et al., 2024; Sarmad et al., 2020).

Risk Management

Project risk management on green engineering projects entailed the identification, evaluation, and control of environmental risks such as pollution, depletion of resources and non-compliance with

regulations (Khoso, et al., 2024; Ahmad, Bibi & Imran, 2023). Studies revealed that green construction projects were associated with special risks such as higher cost of materials and regulatory issues (Mohandes et al., 2025; Hwang & Tan, 2012; Bukhari et al., 2024). The mitigation measures were effective in nature, such as environmental monitoring, compliance systems and risk identification at the early stages. Risk management frameworks also ensured that environmental standards were upheld in the course of executing the projects.

Stakeholder Engagement

The coordination among stakeholders is regarded as a key approach to accomplishing SE aims. There was coordination between the engineers, clients, regulatory and local communities through communication strategies. Research pointed out that the performance of project sustainability was greatly affected by the involvement of stakeholders (Kehinde, 2025; Opoku et al., 2024; Bukhari, 2025; Khan et al., 2021). Active stakeholder participation enhanced transparency and minimized opposition to sustainable practices. Community and regulatory stakeholders were significant in the environmental compliance and accountability.

Sustainability Performance

In engineering projects, sustainability performance was gauged using indicators of energy efficiency, waste reduction, emissions control, and optimization of resources. Recent research indicates that projects which incorporated organized project management practices scored higher in terms of environmental performance (Shah et al., 2023; Owusu-Manu et al., 2022). The environmental footprints were significantly minimized through energy-efficient designs and waste management strategies (Noor et al., 2024). Project monitoring systems had to include more and more emission control mechanisms to ensure that the environmental regulations were adhered to.

Theoretical Framework

Stakeholder Theory is popular in studies on sustainability and implies that successful project performance is based on successful involvement and engagement of all stakeholders. It is now being applied to describe the effects of communication and collaboration on sustainability outcomes of engineering projects (Opoku et al., 2024; Jacob & Joseph, 2024). The Resource-Based View (RBV) theory is also used to make sense of the contribution of efficient utilization of resources towards competitive advantage and sustainability performance. The combination of these two theories explains the support for environmental sustainability in engineering project management through organizational capabilities and interactions among stakeholders (Kehinde, 2025; Malik et al., 2023).

Hypotheses Development

H1: Project planning has a significant positive impact on sustainability performance

H2: Risk management has a significant positive impact on sustainability performance

H3: Stakeholder engagement has a significant positive impact on sustainability performance

H4: Project management practices collectively have a significant impact on environmental sustainability outcomes

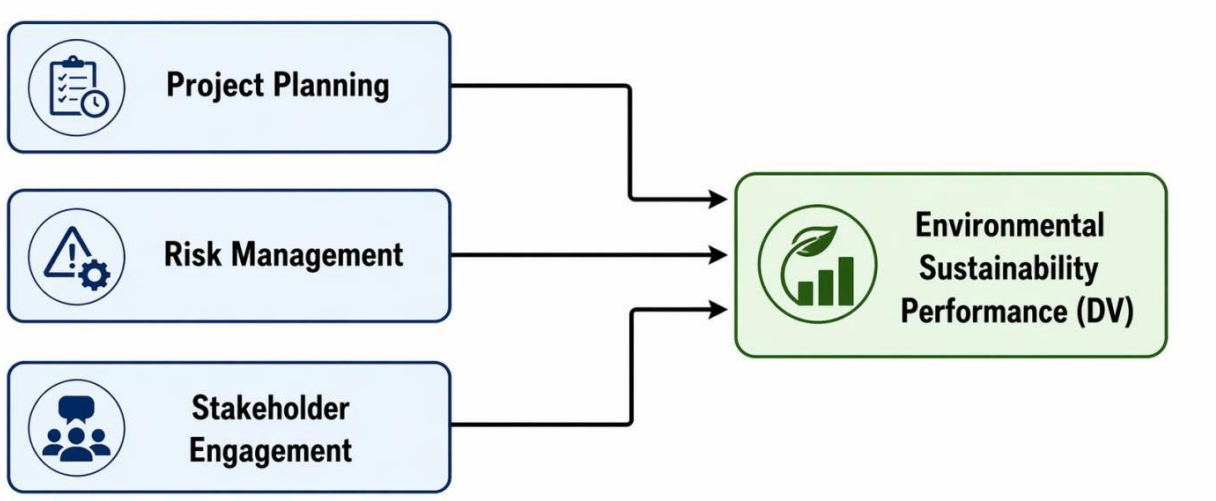
Conceptual Framework

This research establishes a theoretical model to exhibit the correlation of PMPs and environmental SP in GE projects (Robichaud & Anantatmula, 2010; Shah et al., 2023). This framework was premised on the idea that proper execution of the main project management dimensions improves sustainability results in the engineering practices (Phung et al., 2022). PP, RM and SE constitute the independent variables (IVs) of this paper. These variables are fundamental PMPs that determine the design, execution, monitoring and controlling of engineering projects relative to environmental goals (Stanitsas et al., 2021; Opoku et al., 2024).

This performance metric reflects the ability of engineering projects to promote energy efficiency, reduce waste and emissions, and improve resource management (Owusu-Manu et al., 2022; Nwaogbe et al., 2025). The framework asserts that effective PP facilitates sustainable execution by efficiently allocating resources and incorporating environmental considerations from the early stages of development. RM enhances the SP by detecting and reducing the environmental risks during the project life cycle (Danish, Akhtar & Imran, 2025; Mankash, et al., 2025). In a similar manner, stakeholder engagement improves the sustainability outcomes through collaboration, transparency, and adherence to the environmental standards (Rosengart et al., 2023; Kehinde, 2025).

These PMPs are likely to contribute beneficially to the environmental sustainability practices in environmentally friendly engineering projects (Shah et al., 2023; Soares et al., 2024). Thus, the conceptual model is structured as follows:

Figure 3.1: *Conceptual Framework of the Study*



Research Methodology

The research employed quantitative techniques alongside a cross-sectional research design for its study. The design was appropriate as it enabled researchers to examine the interactions between variables at a single point in time. Such an approach is widely used in engineering and sustainability research where hypothesis testing and statistical generalization are required (Saunders et al., 2011). The paper was grounded in a positivist research paradigm and employed a deductive approach which is suitable to test the pre-established hypotheses (Creswell & Creswell, 2017).

The research was conducted within green engineering project settings in Pakistan, specifically targeting engineering and construction firms, infrastructure development agencies, and organizations engaged in sustainability-focused projects. These included companies involved in renewable energy projects (e.g., solar and wind installations), green building construction, and environmentally sustainable infrastructure development. The 12 organizations that participated, located in major urban and industrial regions including Islamabad, (Lahore), and (Karachi). These organizations were selected based on the following inclusion criteria: (i) active involvement in projects incorporating environmental sustainability principles, (ii) implementation of formal project management practices, and (iii) volunteer participation. These settings were chosen due to their demonstrated engagement with sustainability practices and structured project management systems aimed at minimizing environmental impact (Kehinde, 2025).

The study population included the managers, engineers and sustainability experts contained in GE. Sustainability professionals will be defined in this study as those people who will be in charge of environmental compliance, sustainability reporting, environmental impact assessment, or the integration of sustainability standards (e.g., LEED or ISO 14001) into a project. The green engineering projects were considered to be the projects that explicitly include the use of feasible environmental design, supply competence and reduced ecological impact in the lifecycle of the venture. A purposive type of sampling method was used to select 250 respondents in terms of their related professional experience in PP, execution, and sustainability management. This method was suitable because it allowed people who are directly engaged in the management or implementation of sustainability-related engineering projects (Khan et al., 2023).

A structured questionnaire utilizing a 5-point Likert scale was used to gather the required data. The questions have been adapted based on existing instruments in previous literature regarding PMPs and SP usage (e.g., Shenhar and Dvir, 2007; Zhu et al., 2010). The adaptations involved rewording items to make them contextually relevant, including local and locally applicable sustainability practices, and simplifying technical words to make it clearer to the respondents. The instrument was pilot tested on 20 professionals to evaluate the instrument in terms of clarity, reliability and validity, which saw slight changes in the wording and structure. Both online and physical distribution were used in data collection to achieve high accessibility and response rates. The standardized instrument also guaranteed stability and dependability of responses (Hair et al., 2019). The constructs were measured with 5-6 items, which incorporated such areas as scheduling, budgeting, risk identification, communication and collaboration. The dependent variable was SP was measured by 6-8 items. The was chosen based on the conceptual frameworks of sustainability measurements developed in engineering research (Li et al., 2024).

The study achieved a high response rate, with all 283 questionnaires distributed returned. However, after data screening, a small number of responses with incomplete or inconsistent entries were identified and excluded, which reduce the sample to only 250.

The data collected were analyzed with SPSS. Also, Structural Equation Modeling (SEM) was taken into consideration for analyzing complex relationships among variables and proving the conceptual model of the study (Tabachnick & Fidell, 2007).

Results

Demographic Profile

Table 1: *Age*

	Frequency (N)	%
20–30 years	62	24.8
31–40 years	98	39.2
41–50 years	64	25.6
51 years and above	26	10.4
Total	**250**	**100.0**

The frequency analysis shows that the majority of respondents (39.2%) were aged 31–40 years.

Table 2: *Gender*

	(N)	%
Male	172	68.8
Female	73	29.2
Prefer not to say	5	2.0
Total	**250**	**100.0**

Results indicate that male respondents dominated the sample (68.8%).

Table 3: *Experience*

	N	%
Less than 2 years	28	11.2
2–5 years	66	26.4
6–10 years	89	35.6
More than 10 years	67	26.8
Total	**250**	**100.0**

Most respondents (35.6%) had 6–10 years of professional experience.

Table 4: *Profession*

	Frequency (N)	Percentage (%)
Project Manager	74	29.6
Engineer	96	38.4
Environmental Specialist	42	16.8
Consultant	28	11.2
Other	10	4.0
Total	**250**	**100.0**

Engineers formed the largest group of respondents (38.4%).

Reliability Analysis (Cronbach's Alpha)

Table 5: *Reliability Statistics*

Construct	Number of Items	Cronbach's Alpha
Project Planning	6	0.84
Risk Management	6	0.86
Stakeholder Engagement	6	0.88
Sustainability Performance	8	0.91
Project Management Practices	5	0.83

All constructs show Cronbach's Alpha values above 0.70, indicating acceptable to excellent internal consistency.

Correlation Analysis (Pearson Correlation)

Table 6: *Correlation Matrix*

Variables	PL	RM	SE	SP
Project Planning (PL)	1	0.62**	0.58**	0.71**
Risk Management (RM)	0.62**	1	0.64**	0.69**
Stakeholder Engagement (SE)	0.58**	0.64**	1	0.74**
Sustainability Performance (SP)	0.71**	0.69**	0.74**	1

Note: $p < 0.01$ (2-tailed)

All independent variables show favorable correlations with SP and are statistically significant. A correlation packet for SE and SP reflects the toughest association seen ($r = 0.74$).

Regression Analysis (Multiple Linear Regression)

Table 7: *Model Summary*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.81	0.66	0.65	0.42

According to the data, the model captures 68% of the variability in SP.

Table 8: *ANOVA*

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	98.21	3	32.74	185.62	0.000
Residual	50.31	246	0.20		
Total	148.52	249			

The regression model is statistically significant ($F = 185.62$, $p < 0.001$), indicating a good model fit.

Table 9: *Regression Coefficients*

Predictor	B	Std. Error	Beta	t	Sig.
Constant	0.52	0.21	—	2.48	0.014
Project Planning	0.31	0.06	0.31	5.42	0.000
Risk Management	0.28	0.06	0.28	4.89	0.000
Stakeholder Engagement	0.36	0.06	0.36	6.21	0.000

Table 5.9 indicates that the predictors have affirmative and considerable impact on SP ($p < 0.001$). SE seems to be the most influential ($\beta = 0.36$), then PL ($\beta = 0.31$) and RM ($\beta = 0.28$). It means that the better those practices are the more sustainability results are achieved, and the most significant variable is SE.

Hypothesis Testing Summary

All variables have statistically significant positive impacts on the SP ($p < 0.001$). Moreover, the general model establishes that the PMPs have a major bearing on the results of ES in the green engineering projects.

Research shows that PMPs play an essential part in boosting student success. SE served as the most powerful predictor among all tested variables while PL and RM followed as the next strongest predictors. The results also affirm that structured PM plays a vital role in ensuring sustainability objectives in engineering projects.

Discussion

The results of this research show that PMPs are instrumental in environmental SP of green engineering projects. In relation to RQ1, the results show that PMPs collectively have a strong positive impact on sustainability outcomes ($\beta = 0.81$, $R^2 = 0.66$). This implies that risk management (RM), stakeholder engagement (SE), and structured planning are not independent activities but

rather interrelated processes that influence environmental performance. The findings validate that engineering projects having well-integrated management systems will always show improved sustainability results, which are consistent with the growing interest in organized sustainability approaches in the engineering practice (Shah et al., 2023; Phung et al., 2022).

Considering RQ2, the research indicates that the three important PMPs, PL, RM and SE, are statistically significant in their relationship with SP. Among these, SE emerges as the firmest forecaster ($\beta = 0.36$), subsequently PL ($\beta = 0.31$) and RM ($\beta = 0.28$). This implies that SE, cooperation is more focal in the attainment of environmental objectives as opposed to technical planning. This observation aligns with the past literature that has stressed the importance of stakeholder integration as a key element in achieving sustainable task results (Kehinde, 2025; Opoku et al., 2024). It is noted that those projects where stakeholders are actively involved are more likely to be more transparent, more capable of adhering to the environmental standards, and exhibit better sustainability performance.

The research results match existing literature because Shah et al. (2023) found that structured PMPs lead to positive environmental results in engineering projects. Mohandes et al. (2025) showed that RM needs to handle environmental uncertainties, which the current results confirm. The research finds that SE serves as the most important variable because previous conceptual frameworks failed to recognize its full value (Rosengart et al., 2023).

The best predictor, which is SE, can be justified by the fact that it incorporates various opinions, such as regulatory requirements, community expectations, and organizational goals. Such integration enhances the quality of decisions made and makes sure that the sustainability contemplations are integrated thoroughly (Opoku et al., 2024). Project planning is also crucial as it guarantees the effective distribution of resources and the initial consideration of environmental goals, whereas risk management is important to monitor environmental risks and eliminate them (Stanitsas et al., 2021).

Regarding the practical implications, the results indicate that engineering companies should focus on the stakeholder engagement mechanisms, including collaborative planning sessions and clear communication strategies. Moreover, project managers should incorporate indicators of sustainability in PP and RM models to enhance environmental performance (Alghamdi, 2025). In general, the research emphasizes that PM is not only a technical aspect but also a strategic instrument in realizing the goals of environmental sustainability in green engineering projects (Soares et al., 2024).

Conclusion

This study has identified the significance of project management practices towards meeting the objectives of environmental sustainability in green engineering projects. The study has tested the connection between these variables with a quantitative approach and discovered that all three variables have a strong and positive effect on environmental outcomes.

The findings affirm that the stakeholder engagement is the strongest influence in enhancing the sustainability performance, then project planning and risk management. It is also clear that the projects that have properly organized management systems are likely to have a greater level of energy efficiency, waste minimization, emission control and resource optimization. The research also shows that sustainability performance cannot be realized alone but relies highly on integrated project management procedures.

Implications and Recommendations

Theoretical Implications

This research enhances the current understanding of project management and sustainability by demonstrating the relationship between management activities and the environmental performance. It reinforces the stakeholder theory and the resource-based view (RBV) because it shows that collaboration, communication, and effective use of resources are essential in terms of sustainability performance. It is proposed that further incorporation of stakeholder engagement into theoretical frameworks of the future must consider stakeholder engagement as a core predictor of environmental success in engineering work.

Practical Implications

Project managers are advised to incorporate sustainability objectives into project planning activities to maintain an early match to environmental goals. Practices of risk management need to be enhanced to enable risk identification and risk mitigation practices across the project lifecycle. Furthermore, organizations should strengthen the stakeholder engagement plan by encouraging the ongoing communication and cooperation among all the project members, such as communities, regulators, and clients. The practices have a great potential to enhance the performance of the environment as well as project efficiency.

Recommendations for Future Research

Future research studies should focus on longitudinal research design to understand how practices of project management can affect sustainability performance in the long run. It is also suggested that future studies be conducted in other countries and in other industrial sectors to enhance the generalizability of the findings. Furthermore, mixed-method designs should be embraced in order to understand the qualitative aspects of sustainability practices in engineering projects.

Conflict of Interest

The authors showed no conflict of interest.

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