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**EXPLORING KEY DETERMINANTS OF GREEN PROCUREMENT
IMPLEMENTATION FOR CONSTRUCTION PROJECTS: A MEASUREMENT
MODEL IN STRUCTURAL EQUATION MODELLING (SEM)**

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Abstract

Green procurement procures goods and services and works to minimize negative impacts throughout their life cycle. It is a concept introduced as a way forward towards a greener approach aligned with Agenda 21 towards sustainable development. The 12th Malaysia Plan emphasized the Malaysian government's strategic commitment to integrate environmental considerations into its procurement processes. This shows Malaysia's commitment towards sustainable development and promoting environmentally responsible practices in the sectors. However, there are several challenges faced by the industry in green procurement (GP) implementation, such as lack of commitment, low awareness and knowledge of green procurement and policy enforcement. This study explores the key determinants, focusing on authority, accountability, policy, and knowledge, that influence green procurement implementation. This study employs quantitative methods, and a questionnaire survey was used as the data collection technique. The data was analyzed using a measurement model in Structural Equation Modelling (SEM) Analysis of Moment Structure (AMOS) version 28 to identify and analyze the interrelationships among influential determinants such as authority, accountability, policy and knowledge of green procurement implementation. The findings highlight the key determinants of green procurement that significantly affects green procurement implementation. Critical insights of the findings provide strategic recommendations to overcome the limitations of current green procurement practices, and by addressing these gaps, this study contributes to more effective green procurement implementation practices in construction projects, highlighting planning & policy formation, compliance, stakeholder engagement, education and knowledge sharing, transparency and accountability, collaboration, management support, guidelines and construction stakeholders role throughout the construction phases.

Keywords: Green procurement; Structural Equation Modeling (SEM); AMOS; Construction; Projects

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INTRODUCTION

The construction industry plays an important role in developing infrastructure and physical facilities for people, and these activities contribute to significant environmental impacts. Transitioning to sustainable practices in the construction industry is now essential due to the rapid environmental changes (Rashid et al., 2022). The concerning impacts on the environment in the construction industry have made people to be more conscious of the importance of sustainable construction practices. Focusing on construction activities, various phases are involved, such as pre-and post-construction stages. During the pre-construction stage, procurement decisions were made, and Witek & Kuźniar (2021) mentioned that environmental considerations had become an important issue in the industry, especially purchasing.

Procurement delivery is crucial for construction projects to ensure adherence to the contract. Greening procurement delivery is particularly important in construction projects. Many strategies have been introduced to minimize environmental impacts, and one of them is the introduction of green procurement (GP). In the 12th Malaysia green growth for sustainability and resilience Plan (2021-2025), the Malaysian government has addressed the importance of advancing, where it highlighted enhancing implementation mechanisms for green practices. Moreover, short-term action plans and guidelines on government green procurement (GGP) will be introduced to foster green practices in the construction sector.

LITERATURE REVIEW

Overview of Green Procurement

Green procurement (GP) can be defined as the "sourcing of products and services that mitigates the potential threat to the environment and human health" (Najmi et al., 2020). As for Government Green Procurement (GGP), it has been defined as the "procurement of supplies, services and works by the government that takes into account environmental criteria to conserve and minimize the impact on the environment, accelerate the national economy and promote sustainable development" (Adham and Siwar, 2012). For construction, the green procurement for works was established, which encompasses the minimization of the environmental impacts of construction works in phases of the lifecycle and other physical infrastructure (Khan et al., 2018).

Green procurement is still in the infancy level in Malaysia, and the current process still suffers from fragmented efforts and insufficient integration of green practices into green procurement strategies (Razali et al., 2021). There are a few challenges in green procurement implementation that need to be addressed to ensure that green procurement can be successfully implemented. Al

Hazza et al. (2023) highlighted a lack of knowledge and awareness of GP, low commitment among construction stakeholders, lack of policy enforcement (AlNuami and Khan, 2019), and limited standard green procurement guidelines (Benjamin et al., 2016). To ensure that green procurement can be implemented effectively and successfully, it is crucial to investigate the key determinants of green procurements. Despite the potential benefits of GP, the implementation of GP practices still needs to be improved across industries, especially in the construction industry.

Key Determinants of Green Procurement Implementation in Construction Projects

Understanding key determinants of green procurement in construction projects within Malaysia is essential to promote sustainability practices and contribute to sustainable development in construction projects. Moreover, the construction stakeholders can adopt a more integrated framework for implementing green practices in construction projects. More empirical evidence and data validation are still needed to address the complex interplay among these critical determinants. Isolated interventions lead to fragmented and ineffective implementation strategies (Erdmenger, 2017). The construction stakeholders need to consider working in collaboration and considering their interdependencies to implement this strategy successfully. According to the theoretical perspectives of collaboration, Mattessich et al. (2001) highlighted authority and accountability as practical collaboration elements, and Pun (2006) highlighted policy as an environmental operations model. On the contrary, Bohari et al. (2020) highlight the importance of creating awareness and green education among construction stakeholders.

From a global perspective, an international awareness exists to achieve sustainable development goals in the construction sector. Most developed countries have national plans targeting public procurement to incorporate environmental considerations and mention public procurement in the national sustainability plan (Lewis et al., 2023). For example, France set a non-binding goal of 100% public procurements at every governance level to include a minimum of one environmental criterion by 2025 in the National Plan for Sustainable Purchases. As for Germany, the Federal Climate Change Act set a similar goal of a climate-neutral federation administration by 2030. In Malaysia, the government has many initiatives and strategies to address environmental issues. Focusing on green procurement for the construction sector, it started with the National Green Technology Policy (2009), which highlights purchasing environmentally friendly and green products and services, which developed through the years with the introduction of the MyHijau Program, a platform to encourage green technology and green purchasing. The Twelfth Malaysia Plan,

2021-2025, emphasized enhancing the green practices implementation where a short-term action plan and guidelines on government green procurement for works will be introduced. While many policies on green procurement are available, compliance within the organization and government in Malaysia needs to be improved (Vejaratnam et al.,2023).

Authority and Accountability

Authority refers to entities or bodies responsible for developing, implementing, and enforcing policies and guidelines. As for accountability, it refers to “the quality or state of being accountable” (Merriam-Webster, 2019).

Policy

According to Bohari et al. (2020), in terms of green-related practices, the government must establish and enforce laws and regulations related to green procurement and provide incentives to promote green procurement. Moreover, the government must implement a code of practices, such as Environment Impact Assessment (EIA), in construction phases to ensure compliance with green procurement standards and regulations. Moreover, the government must set mandatory requirements and compliance for tenders, and it is crucial to obtain government approval to incorporate green practices in the early stages of the projects.

Knowledge

According to Bohari et al. (2020), it is essential to create awareness and educate the construction project stakeholders before the project commences and throughout the project's life cycle. Understanding and knowledge can facilitate participation and collaboration among construction stakeholders. Informal training, project meetings, and benchmarking can improve construction stakeholders' awareness of green procurement. By synthesizing these aspects, the key determinants of green procurement can be further investigated. A critical limitation exists in understanding how these determinants interact with and collectively impact green procurement implementation. Therefore, this study examines the essential determinants of green procurement implementation in Malaysia, driven by the need to enhance environmental sustainability and organizational efficiency.

RESEARCH METHODOLOGY

This study uses a quantitative approach for the primary data and an integrative review for secondary data. The primary data was collected through questionnaire surveys. The data collection technique used was hardcopy and online distribution

(web-based survey) using Google Forms, designed using a Likert scale of 1 to 5. The sampling technique used for this study involved a multistage approach, where purposive sampling was used to identify certified green building projects and choose types of construction stakeholders in Peninsula Malaysia (Klang Valley), Sabah, and Sarawak for the selection of the study areas by region cluster sampling. The sample size for this study was determined by using Krejcie and Morgan's (1970) table based on the respondents' population size of 180, and the recommended sample size for this study was 123. This study employs Covariance-Based Structural Equation Modelling (CB-SEM) with the use of the CB-SEM tool, Analysis of Moment Structures (AMOS) version 28, to systematically analyze the interdependencies among key determinants such as policy, commitment, knowledge and guidelines.

As for the data analysis, descriptive statistics will be used to summarize the demographic data, and as for SEM, the identification of model specifications is essential for developing structural Equation Modeling. The model types involved in this study are confirmatory factor analysis (CFA) to validate the procedure for measurement model and development of structural equations modelling (SEM). This study's exogenous (independent) variables are authority and accountability, and the endogenous (dependent) variables are green procurement implementation. The CFA will be assessed on the reliability and validity tests, such as construct validity, to examine the fitness indexes and test the convergent validity, composite reliability, and discriminant validity before developing the structural model. Analysis and interpretation of the data from the model are carried out to answer the formulated problem and the study's objective.

ANALYSIS AND DISCUSSION

Demographic Data

Table 1 and Table 2 show the demographic data for the respondents and no. of respondent's involvement in green projects. The data indicates that Quantity Surveyors are the highest respondents in this study, with 50% in total. Civil and Structural Engineers represent 19% of the total, while Architects and Green Facilitators represent 9.5%. Mechanical and Electrical Engineers comprise 4.8%, and the remaining 7.1% fall into the "Others" category. "Others" in the category represent Green Building consultants, Environment Officers, Contract Administrators, and Procurement Executives.

Table 1. Respondent's professional role
Professional role

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Architect	12	9.5	9.5	9.5
	Civil and Structural Engineer	24	19.0	19.0	28.6
	Mechanical and Electrical Engineer	6	4.8	4.8	33.3
	Quantity Surveyor	63	50.0	50.0	83.3
	Green Facilitator	12	9.5	9.5	92.9
	Others	9	7.1	7.1	100.0
	Total	126	100.0	100.0	

Table 2 reveals most of the respondents have participated in the green projects fewer than three projects with 63.5%. About 11.1% have been involved in 4-6 projects, while 1.6% have participated in 7-9 projects. As a smaller group, 7.9% have been involved in more than ten projects. Additionally, 15.9% of respondents have not been involved in green projects. Overall, the data shows varying levels of engagement, with the majority having limited experience in green projects. From these green projects, involvement will provide insights from those with more involvement in green projects, and the respondents who have not participated in any green projects highlight the respondents who may have theoretical or outlying knowledge of green projects.

Table 2. No of Respondent's Involvement in Green Projects
Total of GP involvement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 3 projects	80	63.5	63.5	63.5
	4-6 projects	14	11.1	11.1	74.6
	7-9 projects	2	1.6	1.6	76.2
	More than 10 projects	10	7.9	7.9	84.1
	No project	20	15.9	15.9	100.0
	Total	126	100.0	100.0	

This demographic data provides a foundational understanding of the respondents, allowing the study to identify and analyze the critical determinants of green procurement implementation from a diverse and representative sample.

Confirmatory Factor Analysis

After analyzing the descriptive statistics for this study. Next, the measurement model was validated by confirmatory factor analysis (CFA), and the constructs went through a validity test to ensure the model fit. Hair et al. (2010) and Holmes-Smith (2007) recommended using at least one fitness index from each category model: Absolute Fit, Incremental Fit, and Parsimonious Fit. Some modifications have been made to make the model fit according to the fitness category, and the fitness indexes used for this study are RMSEA, CFI and CMIN/Df. Figure 1 is the measurement model for this study;

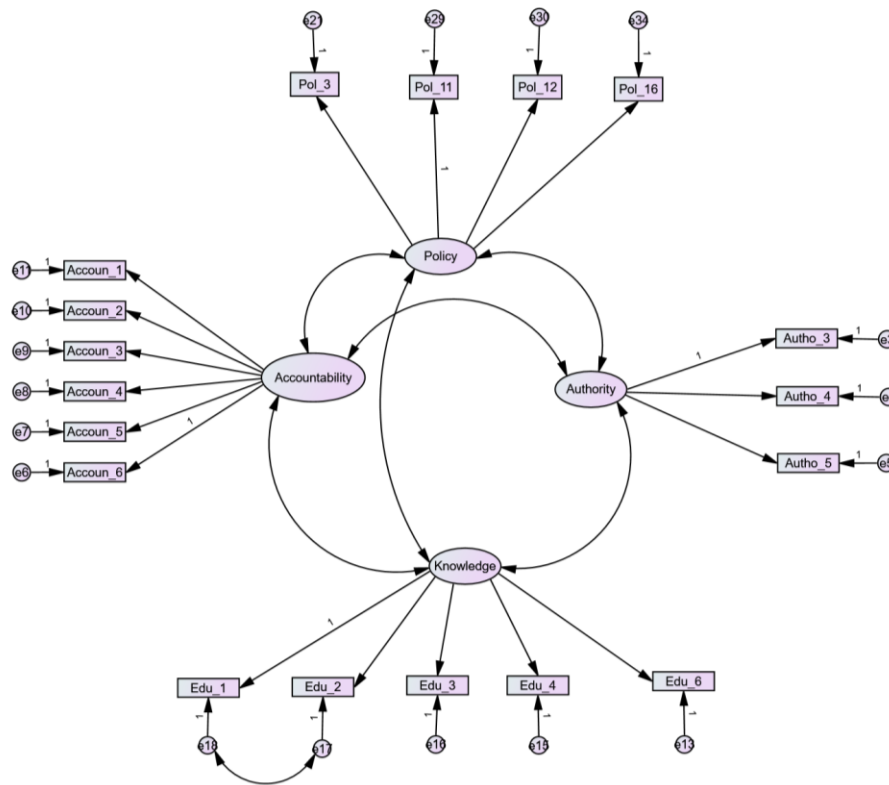


Figure 1. The measurement model

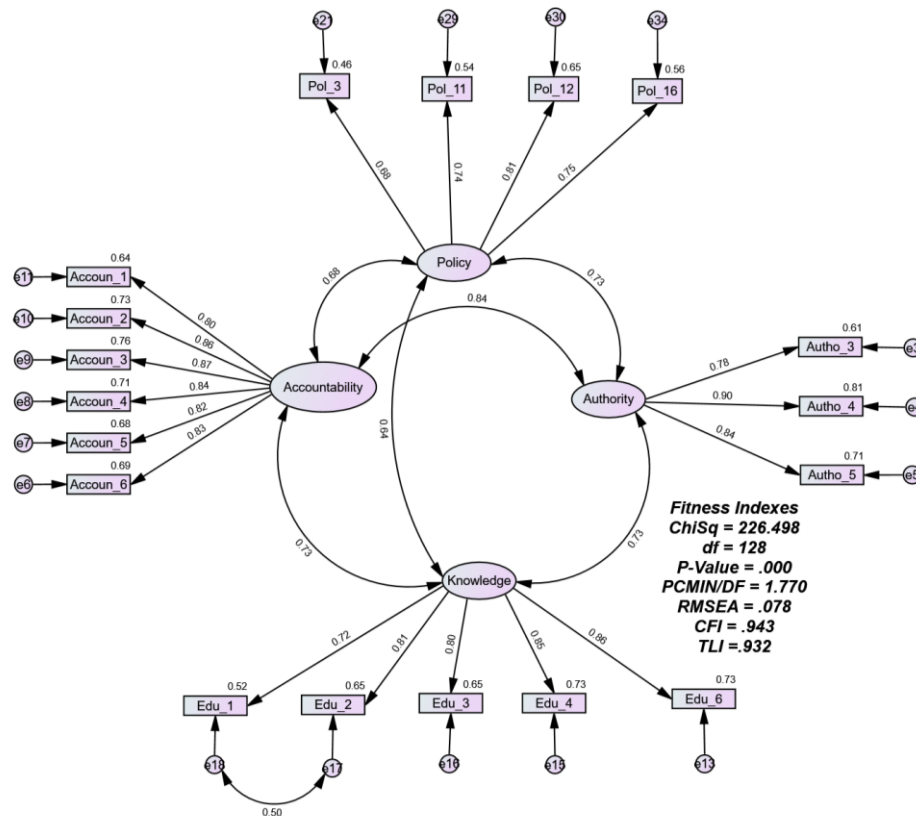


Figure 2. CFA results for the measurement mode

Figure 2 shows the CFA results for each component after model modifications for the measurement model. The variables for Authority are Autho_3, Autho_4 and Autho_5. Whereas the accountability is Accoun_1, Accoun_2, Accoun_3, Accoun_4, Accoun_5, and Accoun_6. Policy is Pol_3, Pol_6, Pol_11, Pol_12 and Pol_16 and Knowledge is Edu_1, Edu_2, Edu_3, Edu_4 and Edu_6. The assessment of Construct Validity is presented in Table 3, and the assessment shows the CFA model achieved the required level of fitness category for Absolute Fit, RMSEA = .078, Incremental Fit, CFI = .943 and Parsimonious Fit, CMIN/df = 1.770.

Table 3. The assessment of construct validity for the Measurement Model after modifications

The Measurement model				
Fitness Category	Name of Index	Index Value	Threshold	Comment
Absolute Fit	RMSEA	.078	<0.08	Achieved the level
Incremental Fit	CFI	.943	>0.95 – CFI>0.85 (acceptable)	Achieved the level
Parsimonious Fit	CMIN/Df	1.770	<3.00	Achieved the level

After the CFA procedure for the measurement model was completed, the factor loading for every construct was analyzed. The determination of convergent and composite reliability is assessed as below;

Table 4. The assessment of convergent and composite reliability

Construct	Item	Factor Loading	CR (> 0.6)	AVE (>0.5)
Authority	Autho_3 Engaging construction stakeholders in decision-making processes	0.78	0.880	0.710
	Autho_4 Project guidelines for the construction stakeholders	0.90		
	Autho_5 Established work guidelines for the project delivery	0.84		
Accountability	Accoun_1 Strong leadership, especially from a leader from each construction stakeholders	0.80	0.934	0.701
	Accoun_2 Clear contractual agreements about green procurement implementation	0.86		
	Accoun_3 Clear rules and regulations for the construction stakeholders	0.87		
	Accoun_4 Providing transparency to construction stakeholders on the whole process of green procurement implementation	0.84		
	Accoun_5	0.82		

Construct	Item	Factor Loading	CR (> 0.6)	AVE (>0.5)
Policy	Construction stakeholders should adhere to environmental regulations and standards			
	Accoun_6	0.83		
	Support from top management on green procurement implementation is important			
	Pol_3	0.69	0.831	0.552
	Policy availability at the project level could encourage environmental awareness			
	Pol_11	0.72		
	The government's initiative to implement green procurement for all large public projects			
Knowledge	Pol_12	0.79		
	The community and government must have efforts and initiatives such as competition/awards, incentive schemes			
	Pol_16	0.75		
	Raising organisation awareness on green procurement (training and institutional organisations)			
	Edu_1	0.72	0.905	0.656
	Awareness of green procurement's concept, importance, benefits, and opportunities through training programs or seminars.			
	Edu_2	0.81		
	Educate the construction stakeholders on environmental consciousness through green procurement implementation			
	Edu_3	0.80		
	Benchmarking international best practices and lessons learned from different governments around the world.			
	Edu_4	0.85		
	Interaction between academia and practitioners to develop knowledge on green procurement			
	Edu_6	0.86		

Construct	Item	Factor Loading	CR (> 0.6)	AVE (>0.5)
	Collective learning at all levels within the organisation to adapt to environmental shifts and challenges			

Table 4 shows the factor loading is above 0.50, and the highest factor loading is 0.90. All measures for AVE are greater than 0.50 and all measures for CR is greater than 0.60. Thus, the Convergent Validity and Composite Reliability for all constructs in the study have been achieved. After the analysis of Convergent validity and Composite Reliability, the discriminant validity was assessed using the Fornell-Larcker Criterion. This criterion states that the correlation between a construct and another must be more significant than the square root of the average variance retrieved by the construct. The calculation of Discriminant Validity and Discriminant Validity Index Summary is shown in Table 5;

Table 5. The Discriminant Validity Index Summary for the construct using the Fornell-Larcker Criterion

	Knowledge	Authority	Accountability	Policy
Knowledge	0.810			
Authority	0.728	0.842		
Accountability	0.731	0.836	0.837	
Policy	0.639	0.733	0.675	0.743

Table 5 shows there are four (4) constructs involved in the model. A 4 by four matrix table was developed. The diagonal values in bold are the square root of the AVE of that construct, while other values are the correlation between the respective constructs. The discriminant validity is achieved when the diagonal value in bold is higher than other values in its row and column. It can be concluded that the discriminant validity for all four constructs (Knowledge, Authority, Accountability and Policy) is achieved. The value of 0.810 for Knowledge is more significant than 0.728, 0.731 and 0.639. The value of 0.842 for authority is greater than 0.836, 0.733 and 0.728. The value of 0.837 for Accountability is greater than 0.675, 0.731, 0.836. The value of 0.743 for Policy is greater than 0.675, 0.733 and 0.639.

From the key determinants and items in Table 6, it is important to consider the various phases and activities involved in construction projects to implement green procurement practices within the construction industry

effectively. The importance of these key determinants of green procurement can enhance the integration of sustainable practices. By aligning specific actions and strategies with each phase, a more systematic and efficient implementation of green procurement can be determined. In this discussion, the key determinants of green procurement implementation were categorized based on construction phases to provide a straightforward approach for green procurement.

Table 6. Key Determinants of Green Procurement Implementation in Construction Projects throughout the Phases.

CONSTRUCTION PHASES					
	Pre-construction		Construction		Post-construction
Policy	Planning & Policy Formation	Accountability	Implementation and Compliance	Educate	Review and Learning
	Policy Availability		Clear Contractual Agreements		Benchmarking Best Practices
	Policies availability and establishment at the project level		Establish clear contracts which include sustainability requirements to ensure compliance.		After project completion, analyze results and compare them with best practices to identify areas for improvement.
Policy	Government Initiatives	Accountability	Adherence to Environmental Regulations	Educate	Collective Learning
	Government Initiatives to incorporate mandates for green procurement into project planning		Construction activities comply with all relevant environmental regulations and standard guidelines.		Continuous learning within the organization to adapt to environmental challenges and improve future green procurement practices.
Policy	Government Efforts				
	Government efforts to give incentive schemes, monetary or non-monetary reward				

	Stakeholder Engagement and Education		Transparency and Accountability		Knowledge Sharing and Collaboration
Authority	<i>Engaging construction stakeholders</i>	Accountability	<i>Transparency</i>	Authority, Educate	<i>Government-Academia-Construction Practitioner Interaction</i>
	Involve all relevant construction stakeholders in pilot projects and the planning process to ensure their input and commitment.		Maintain transparency throughout the construction process to build trust.		Encourage collaboration between these stakeholders to set the stage, provide standard guidelines for green procurement to drive innovation, disseminate knowledge, bridge information and knowledge gaps, and develop practical solutions for future projects.
Educate	<i>Training Programs</i>	Accountability	<i>Strong leadership</i>		
	Conduct training programs to raise awareness about the benefits and processes of green procurement.		Leadership is crucial in driving the green procurement agenda. Government/Clients should have sustainability initiatives and ensure adherence to green procurement practices.		
Educate	<i>Environmental Education</i>				
	Educate construction stakeholders on environmental issues.				
	Leadership and Management Support		Construction Stakeholders Guidelines and Roles		
Accountability	<i>Support from Top Management</i>	Authority	<i>Project Guidelines for Stakeholders</i>		
	Ensure top management's commitment to providing resources and prioritising sustainability.		Provide clear guidelines for construction stakeholders, defining construction stakeholders' roles and responsibilities in the green procurement process.		

This approach for green procurement in construction phases highlights government initiatives that drive policy formation and integration of sustainability mandates into project planning, which is supported by adherence and compliance to environmental regulations and stakeholder's education. Clear contractual agreements during construction are essential to ensure compliance and are complemented by ongoing education and transparency among the construction stakeholders to enhance accountability and trust. In the post-construction phase, the results of the green procurement project need to be analysed and compared with the best practices to enable continuous learning and improvement. The construction stakeholder's collaboration drives innovation and knowledge sharing. Strong leadership and management support are essential to ensure commitment towards sustainability, and defining the roles and guidelines for construction stakeholders is also vital. These efforts establish a comprehensive approach to green procurement and provide strategic recommendations to overcome the limitations of current green procurement practices. Moreover, this promotes environmental responsibility among construction stakeholders across the construction industry.

CONCLUSION

This study has comprehensively explored the key determinants influencing the implementation of green procurement in construction projects, focusing these four (4) keys determinants, authority, accountability, policy and knowledge. Through the application of Covariance-Based Structural Equation Modelling (CB-SEM) and AMOS analysis, significant insights were gathered that highlight the importance of strong policy frameworks, commitment, and inclusive construction stakeholder education. The findings reveal that established project and work guidelines for construction stakeholders, authoritative support, and clear accountability mechanisms are crucial to enforce the green procurement practices and standards. The government must set the stage for green procurement implementation in terms of policy, whereby it has to be meticulously constructed and thoroughly enforced to ensure compliance among construction stakeholders. Without the enforcement, it will be challenging to implement green procurement. Moreover, transparency is vital to building engagement and trust among construction stakeholders. This study also highlights that ongoing dissemination of knowledge and continuous learning by expert academician is important for bridging information and filling knowledge gaps on green procurement. After the project completion, the evaluation and outcome of green procurement implementation in a project can be further improved by benchmarking against best practices and lessons learned from other countries. This study's critical insights and strategic recommendations provide a way forward to overcome the current limitations in green procurement practices within construction projects.

Addressing the gaps in the construction phases will enhance the effectiveness of green procurement implementation. Emphasizing the importance of education and knowledge sharing among stakeholders will enhance a more insightful understanding and commitment towards green practices. Further research should examine the deeper interactions between these determinants to refine green procurement strategies using structural model analysis. These efforts contribute towards environmental responsibility within the construction industry, paving the way for more sustainable development practices.

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