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# SIGNIFICANT FACTORS INHIBITING THE USE OF SUSTAINABLE CONSTRUCTION MATERIALS AND PRACTICES IN THE BUILT ENVIRONMENT

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**ABSTRACT**

*The construction industry in Kenya is increasingly being called upon to align with global sustainability goals through the adoption of environmentally responsible materials and practices. Despite the evident environmental and economic benefits of sustainable construction, uptake in the Kenyan built environment remains limited. This study investigates the inhibiting factors affecting the adoption of sustainable construction materials and practices. Using a descriptive research design, data were collected from 439 respondents through structured questionnaires, targeting key professionals across the construction value chain. Quantitative analysis, including frequency distribution, mean scores, and standard deviation computations, was used to assess stakeholder perceptions of nine commonly cited adoption barriers. The results reveal that lack of appropriate skills, regulatory challenges, high initial costs, uncertainty about material performance, and limited market demand are the most significant constraints, with most barriers receiving mean scores above 3.8 on a 5-point Likert scale. The findings confirm that systemic issues, spanning human capital, policy coherence, financial incentives, and market perceptions, continue to impede the* *transition toward sustainability. It is concluded that these barriers are interconnected and require coordinated interventions. The study recommends curriculum reform, regulatory harmonization, targeted fiscal incentives, enhanced awareness campaigns, inclusive policy development, and continuous research to facilitate the broader adoption of sustainable construction practices in Kenya.*

**Keywords:** Sustainable construction, Adoption barriers, Green building materials, Construction industry in Kenya, Policy and regulation

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## 1. INTRODUCTION

The built environment (BE) is central to global economic development, urbanisation, and population growth, yet it significantly contributes to environmental degradation [1]. Globally, the construction and operation of buildings account for approximately 39% of carbon dioxide ($CO_2$) emissions and 36% of energy use [2]. These emphasize the urgent need for transitioning towards sustainable construction practices. Despite the growing awareness of sustainability issues, the implementation of sustainable materials and practices in construction remains sporadic and underutilized, especially in developing economies.

Among the most pressing concerns is the carbon intensity of conventional building materials, particularly cement and steel [3]. Cement alone is responsible for about 8% of global $CO_2$ emissions [4,5]. This substantial figure results from both the energy-intensive clinker production process and the calcination of limestone, which releases large volumes of $CO_2$. With cement production exceeding 4 billion tonnes annually, and demand projected to rise due to urban growth, especially in the Global South, mitigating emissions from cement usage has become an urgent priority [6].

Despite numerous technological advancements and materials research promoting alternatives such as fly ash [7], blast furnace slag [8], eggshell powder [3], and other agro-waste derivatives [9], these sustainable materials have not been adopted widely in practice. The disparity between knowledge and implementation signals the existence of significant barriers that inhibit the transition to sustainable practices in construction.

Construction waste contributes to roughly 36% of all solid waste in the European Union, and the linear model of 'extract-produce-use-dispose' remains the default in much of the global construction industry [10]. This unsustainable paradigm worsens resource depletion, waste accumulation, and climate impacts, reinforcing the need for a transition to circular construction models. Circular economy principles, such as reusing building components and regenerating natural systems, have not been fully integrated into mainstream construction workflows due to technical, economic, and regulatory obstacles.

A variety of interrelated factors contribute to the underutilization of sustainable construction materials. These include: Economic Constraints, where sustainable materials are often perceived as more expensive upfront, despite long-term savings through energy efficiency and durability [11]. In cost-sensitive markets, this initial capital requirement acts as a critical deterrent. Lack of Awareness and Education: Many industry stakeholders, particularly small-to-medium enterprises, lack adequate knowledge about the benefits and availability of sustainable materials [12]. Technological and Infrastructure Limitations: The absence of appropriate testing facilities, certification schemes, and manufacturing capabilities for novel materials hinders market readiness and confidence [13]. Policy and Regulatory Gaps: Inconsistent or absent policies that mandate or incentivise sustainable construction have stymied adoption [14]. While certifications like Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), and Comprehensive Assessment System for Built Environment Efficiency (CASBEE) exist [15], their uptake is not universal and often voluntary. Cultural Resistance and Risk Aversion: Construction firms tend to prefer proven materials and methods due to concerns about liability, unfamiliar performance profiles, or a general resistance to change [16]. Supply Chain Fragmentation: The construction industry often relies on fragmented supply chains, which hinders coordination and dissemination of innovations [17].

The result is a critical implementation gap between sustainable construction knowledge and its application, which undermines international climate targets and sustainable development goals. To address this challenge, emerging research calls for integrated strategies that span policy reform, technological innovation, and stakeholder education. Thus, the current study investigates the key barriers that inhibit the widespread adoption of sustainable construction materials and practices within the built environment. It aims to identify, categorizes, and analyses these barriers through a critical review of peer-reviewed literature, with the goal of informing targeted interventions that can accelerate the transition towards sustainable and low-carbon construction systems.

## 2. RELATED WORKS

### 2.1 Theoretical Frameworks

Industrial Ecology Theory offers a relevant lens for examining the factors inhibiting the use of sustainable construction materials and practices in the built environment [18]. By modelling construction systems after natural ecosystems, the theory promotes efficient resource use, waste minimisation, and circularity, principles often lacking in traditional construction. In Kenya's context, where urbanisation, ecological strain, and resource scarcity are intensifying, this framework highlights several barriers to sustainable adoption. Material circularity, a core concept of the theory, reveals practical challenges such as limited reuse infrastructure, poor market acceptance of alternative materials, and inadequate regulatory support [19]. The theory's emphasis on life cycle thinking exposes gaps in data availability, technical expertise, and policy integration that limit the use of life cycle assessments in material selection. Industrial Ecology's emphasis on cross-sector collaboration, such as between construction and agro-industries, identifies institutional silos and weak industrial linkages as key barriers [19]. The systemic perspective encouraged by the theory points to fragmented urban planning and the lack of cohesive sustainability standards as significant constraints. In sum, Industrial Ecology helps frame the problem not as a lack of awareness, but as a series of interconnected structural, technical, and institutional obstacles inhibiting sustainable transformation in the built environment.

### 2.2 Empirical Review

[20] study identifies the construction industry as a major consumer of resources and emitter of carbon, highlighting the issue of excessive waste and lack of circularity. Using a qualitative review, the authors analyzed building deconstruction as a sustainable strategy to promote material reuse. Through literature synthesis and case reviews, they emphasized that regulatory gaps, lack of standard design practices, and limited technical knowledge are barriers to adopting deconstruction. The study concludes that while the reuse of materials has potential, policy alignment and training are required to overcome the inertia toward traditional demolition practices.

[21] study focuses on the financial barriers hindering the uptake of green building practices. Using a scoping review across 28 studies, the authors found a persistent green finance

gap in the building sector. Most buildings fail to access green finance due to lack of policy support, risk-averse financial institutions, and inadequate awareness. Empirical work was limited, revealing a major research gap. The study concludes that targeted financial instruments, incentives, and assessment tools are critical for promoting sustainable practices.

[5] review identifies carbon emissions and energy consumption as dominant sustainability concerns in the construction phase. Through an extensive literature analysis, the authors examined barriers such as lack of sustainable material availability, high costs, and absence of green policy frameworks. The review also emphasized insufficient use of life cycle assessment models. The conclusion advocates for integrating green materials, policy reforms, and education to enhance green construction adoption in low-carbon cities.

[22] study explores digital twins (DTs) as a technology to promote sustainability in the built environment. Using semi-structured interviews with industry experts and a literature review, the study identified barriers to DT implementation: interoperability issues, data security concerns, and resistance to technological change. While DTs have potential to reduce resource usage and enhance material optimization, the lack of industry readiness hinders their adoption. The study concludes that standardization and industry-specific digital tools are required.

[23] differentiates between digital twins and digital shadows, proposing the former as essential for sustainable development in construction. The study critiques the underutilization of smart technologies in material and energy management. Through a conceptual review, it identifies poor digital infrastructure and limited stakeholder collaboration as major inhibitors. The author concludes that integrating digital solutions could accelerate the transition to sustainable practices but requires broader acceptance and policy alignment. Table 1 summarizes the research gap and critique of the selected studies.

Table 1: Summary of research gap and critique of empirical review

| Author | Study Variables | Findings | Research Gap | Critique |
|---|---|---|---|---|
| [20] | Building deconstruction, circular economy | Limited adoption of deconstruction due to regulatory voids and lack of awareness | Empirical validation of deconstruction potential and stakeholder behavior | Strong theoretical grounding but lacks implementation data in diverse regions |
| [21] | Green finance, investment gaps | Financing barriers, lack of incentives, and low awareness | Insufficient empirical research on financing models | Comprehensive scoping but lacks case-specific data |

| | | | | |
|---|---|---|---|---|
| | | hinder adoption of green buildings | applicable to developing economies | for tailored policy advice |
| [5] | Carbon emissions, green construction barriers | High material cost, limited supply of sustainable materials, and weak policies impede adoption | Need for empirical testing of LCA models and material performance in practice | Broad review with strong LCA context but lacks quantification of local-scale emissions |
| [22] | Digital twins, technology implementation barriers | Interoperability issues, technological resistance, and absence of unified standards inhibit sustainable digital transitions | Few studies exploring DT in operational green construction contexts | Focused on technology with limited insight into sociopolitical adoption challenges |
| [23] | Industry 4.0, digital twins, smart construction | Digital twins underutilized due to lack of digital readiness and coordination among stakeholders | More practical, cross-sector research needed to evaluate DTs' contribution to material sustainability | Strong conceptual clarity but lacks practical evidence from ongoing construction projects |

Table 1 indicate that while previous studies have examined aspects of sustainability in construction, they differ significantly from the proposed research. [20] focus specifically on deconstruction and material reuse, while [21] emphasize financial barriers, particularly green finance. [5] provide a broad policy-level review without addressing project-level implementation barriers. [22,23] concentrate on digital technologies, overlooking non-technological inhibitors. The proposed study adopts a comprehensive perspective by empirically investigating the multifaceted factors, economic, institutional, technological, and cultural, that hinder the adoption of sustainable materials and practices in the built environment.

## 3. METHODOLOGY

This study investigated the significant factors inhibiting the adoption of sustainable construction materials and practices in Kenya's built environment. A **quantitative, cross-sectional descriptive survey** was employed to capture the perceptions of construction professionals on key barriers to sustainable construction. The methodology encompassed questionnaire design, purposive sampling, data collection, and statistical analysis using R programming. While the design provides a broad overview of practitioner sentiment, it is acknowledged that the findings reflect **perceptions rather than verifiable practices**, and results should be interpreted as **indicative** rather than conclusive.

### 3.1 Questionnaire Design

The primary data collection instrument was a structured questionnaire developed based on a detailed review of current literature and aligned with the study objective. The instrument contained both closed and open-ended items grouped into thematic sections, with a specific focus on **inhibiting factors** to sustainable construction adoption.

Respondents were presented with a predefined list of **nine potential barriers**, including high initial costs, lack of technical skills, regulatory uncertainty, and limited market demand. For each challenge, respondents rated the **degree of importance** on a **5-point Likert scale**, where 1 represented "Not at all" and 5 "To a very great extent." This design enabled the quantification of perceived barrier severity across the professional community. Additional demographic sections captured data on respondents' roles, experience, and institutional affiliations, providing context for the analysis.

### 3.2 Sampling and Data Collection

A **purposive sampling method** was employed to target industry professionals with relevant expertise in the Kenyan construction sector. These included architects, engineers, quantity surveyors, project managers, developers, and contractors, individuals engaged in planning, designing, financing, or implementing construction projects. This method was chosen to ensure insights from informed stakeholders actively involved in construction decision-making processes.

The survey was distributed both electronically and in print to over 500 professionals across Kenya's major counties. A total of **439 valid responses** were obtained, reflecting a **response rate of 87.8%**. Despite this high return, the sample predominantly included senior professionals and private-sector stakeholders, which introduces **selection bias** and limits the **generalizability** of the findings to the broader sector, particularly among informal builders, rural actors, and public-sector agents.

### 3.3 Data Processing and Analysis

Responses were coded and entered into **Microsoft Excel**, then imported into **R (version 4.5.1)** for statistical analysis. Data cleaning was conducted using the **dplyr** package to handle missing values and ensure consistency. Descriptive statistics, frequencies, percentages, means, and standard deviations, were calculated using packages such as **summarytools** and **psych**.

The analysis focused on the **relative importance of the nine identified inhibiting factors**. Each factor's average Likert score was computed to determine the **perceived level of influence** on adoption decisions. However, **no inferential statistics** such as regression or correlation tests were conducted; as such, the findings cannot establish **causal relationships** or **predictive associations**. The **cross-sectional design** prevents observation of changes over time, and the absence of triangulation with project audits or policy documents limits the ability to verify the perceptions expressed.

While several factors such as high costs and regulatory uncertainty were rated highly, some technologies designated as “adopted” in prior work showed **very low absolute adoption counts**, raising questions regarding statistical power. As such, the results should be viewed as a **diagnostic snapshot of expert opinion**, offering valuable insight for hypothesis generation and future policy discussions, rather than definitive evidence for sector-wide transformation.

## 4. RESULTS AND FINDINGS

### 4.1 Questionnaire Return Rate and Validity

The reported 100% (439 respondents) questionnaire response rate represents a notable achievement in the construction industry research, where response fatigue, limited availability of professionals, and logistical barriers often result in suboptimal participation. In this study, several methodological factors contributed to this success. Purposive sampling ensured that only relevant and informed professionals, such as architects, engineers, and project managers, were included. These participants were more likely to appreciate the importance of the study and thus engage meaningfully. The targeted distribution strategy, combining structured in-person engagements and digital dissemination, allowed for effective reach and follow-up. This dual-mode approach, supported by the researcher's active involvement, eliminated common issues like ignored email surveys or misrouted questionnaires. Such deliberate engagement fostered trust and clarity, which are crucial in ensuring response compliance, particularly in sectors characterized by busy professionals and project deadlines. The manageable sample size and the geographic focus on Kenya’s major counties made it feasible to follow up and collect complete data sets. This aligns with the study’s use of a cross-sectional descriptive survey design, which benefits from snapshot-style data collection when done thoroughly.

Complementing the high response rate, the questionnaire demonstrated strong internal consistency, as evidenced by an average Cronbach’s alpha value of 0.745. This figure falls within the acceptable range (0.70–0.79), suggesting that the instrument items measuring perceived barriers to sustainable construction adoption were coherent and conceptually aligned. This degree of reliability indicates that respondents interpreted the questionnaire items consistently, and that the data collected are robust enough for descriptive statistical analysis and interpretation. From a research quality perspective, this internal consistency lends credibility to the study's key conclusions, particularly regarding the severity and prioritization of barriers such as high initial costs, regulatory uncertainty, inadequate technical capacity, and low market demand. While the study acknowledged that it was limited to perception-based findings without inferential statistical analysis, the reliability of the instrument affirms that the identified trends genuinely reflect stakeholder viewpoints.

Combining the 100% response rate and acceptable reliability score significantly enhance the validity and trustworthiness of the study's findings. These methodological strengths support the claim that the identified inhibiting factors are not only relevant but were systematically and rigorously gathered, thereby reinforcing the study's value for policy formulation and future research on sustainable construction. Table 2 summarizes the distribution of respondents by profession.

Table 2: Distribution of Respondents by Profession

| **Profession** | **Number of Respondents** | **Remarks** |
|---|---|---|
| Construction Project Managers | 114 | Highest representation; key role in execution and project oversight |
| End Users | 112 | Significant input from material/product consumers |
| Quantity Surveyors | 90 | Strong presence; expertise in cost and resource management |
| Engineers | 48 | Provides technical insights into sustainable material application |
| Architects | 33 | Involved in planning, design, and material selection |
| Contractors | 16 | Field-based perspectives on material feasibility and implementation |
| Developers | 13 | Investors and decision-makers on material adoption |
| Others (students, clerks, etc.) | 1–2 each | Include students, data clerks, plumbers, estate agents, trainers, etc. |

Table 2 ndicates that the study primarily engaged core stakeholders in the construction industry. Construction Project Managers (114), End Users (112), Quantity Surveyors (90), Engineers (48), and Architects (33) accounted for the majority, offering insights grounded in technical expertise and decision-making roles. Contractors (16) and Developers (13) further enriched the data with practical and investment perspectives. However, peripheral roles such as students, estate agents, technicians, and plumbers were minimally represented, with only one or two respondents each. This skew limits the exploration of grassroots-level challenges in adopting sustainable construction materials and practices within the built environment. Table 3 summarizes the distribution of respondents by professional experience.

Table 3: Distribution of Respondents by Professional Experience

| Years of Experience | Percentage of Respondents | Remarks |
|---|---|---|
| 11–15 years | 65.1% | Majority of respondents; seasoned professionals with deep industry insight |
| 6–10 years | 23.2% | Mid-career professionals; likely to be in technical or managerial roles |
| Above 15 years | 7.6% | Senior experts; valuable for strategic insights and long-term observations |
| 0–2 years | 3.1% | Early-career professionals; limited exposure, but emerging perspectives |
| 3–5 years | 0.9% | Relatively underrepresented; entry-to-mid-level contributors |

Table 3 indicate that the study predominantly captured the views of highly experienced professionals (11–15 years), who are well-positioned to assess the challenges and opportunities in adopting sustainable construction materials. The low representation of early-career respondents (0–5 years) suggests limited input from emerging practitioners, which may constrain the understanding of fresh perspectives or innovative tendencies among the younger workforce. Table 4 presents distribution of respondents by organization type.

Table 5: Distribution of Respondents by Organization Type

| Organization Type | Number of Respondents | Percentage (%) | Remarks |
|---|---|---|---|
| Private Companies | 237 | 53.98% | Dominant group; central to implementation and market-led sustainability |
| Government Agencies | 43 | ~9.8% | Key for policy, regulation, and public infrastructure programs |

| | | | |
|---|---|---|---|
| NGOs | 32 | ~7.3% | Active in advocacy, training, and community-level sustainability projects |
| Students | 8 | ~1.8% | Represent future professionals and academic viewpoints |
| International Organizations | 1 | ~0.2% | Minimal input; limited global institutional presence in sample |
| Schools | 1 | ~0.2% | Very limited academic institutional participation |
| Universities | 1 | ~0.2% | Indicates minimal higher education sector engagement |
| Self-Employed | 1 | ~0.2% | Reflects independent practice perspective |
| Unemployed | 1 | ~0.2% | Marginal representation from non-active professionals |
| Private & Government (Dual Affiliation) | 1 | ~0.2% | Hybrid role; possibly consultant or policy-linked |
| Student (Duplicate Entry) | 1 | ~0.2% | Likely a data entry error |

Table 4 indicate that the organizational affiliation of respondents reveals a strong dominance of the private sector, comprising 53.98% of the sample. This indicates that private firms are pivotal in shaping construction practices and could either drive or hinder sustainability based on their economic and regulatory context. Government agencies and NGOs, with 43 and 32 respondents respectively, provide important perspectives on policy enforcement and community-level implementation. However, academia, international organizations, and independent professionals were minimally represented. While the private sector's heavy presence ensures relevance to practice, the limited diversity of institutional perspectives may constrain the study's ability to fully explore systemic barriers and cross-sectoral solutions.

**4.2 Factors Inhibiting the use of Sustainable Construction Materials and Practices in the Built Environment**

This section expounds the empirical findings on the key perceived barriers impeding the uptake of sustainable construction materials and practices within the Kenyan built environment. Identifying and critically assessing these inhibiting factors is essential for aligning the construction sector with national and global sustainability agendas. To facilitate a structured evaluation, respondents were presented with a curated list of widely recognized challenges and asked to rate their perceived significance on a five-point Likert scale: 1 (Not at all) to 5 (Very great extent). This measurement framework enabled the systematic quantification of stakeholder insights regarding the relative severity of each barrier. The resulting data, comprising frequency distributions, mean scores, and standard deviation values, offers detailed evidence of consensus and variability in perceptions across the professional spectrum. These findings are detailed in Table 5, providing a robust foundation for targeted policy and strategic interventions.

Table 6: Inhibiting Factors to the Adoption of Sustainable Construction Materials and Practices.

| CHALLENGES | Not at all (1) | Little extent (2) | Moderate extent (3) | Great extent (4) | Very great extent (5) | Mean | SD |
|---|---|---|---|---|---|---|---|
| Lack of appropriate skill towards new construction using sustainable materials and techniques (deficient knowledge to produce specifications) | 10 (3.06%) | 23 (7.03%) | 83 (25.38%) | 97 (29.66%) | 114 (34.86%) | 3.86 | 1.07 |
| Difficulties in gaining approval of new technologies for building codes and uncertainty about approvals | 14 (4.28%) | 34 (10.4%) | 88 (26.91%) | 100 (30.58%) | 91 (27.83%) | 3.67 | 1.11 |
| Conflicting building codes | 23 (7.03%) | 35 (10.7%) | 86 (26.3%) | 99 (30.28%) | 84 (25.69%) | 3.57 | 1.18 |
| Lack of financial incentives by government | 14 (4.28%) | 19 (5.81%) | 54 (16.51%) | 99 (30.28%) | 141 (43.12%) | 4.02 | 1.1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Uncertainty of the performance of sustainable construction materials and practices | 16 (4.89%) | 24 (7.34%) | 64 (19.57%) | 110 (33.64%) | 113 (34.56%) | 3.86 | 1.12 |
| Inadequate inclusivity of education curricula coverage on sustainable construction materials and practices | 14 (4.28%) | 24 (7.34%) | 69 (21.1%) | 106 (32.42%) | 114 (34.86%) | 3.86 | 1.1 |
| Low or limited market demand | 17 (5.2%) | 24 (7.34%) | 85 (25.99%) | 95 (29.05%) | 106 (32.42%) | 3.76 | 1.14 |
| Lack of belief in perceived benefits | 14 (4.28%) | 23 (7.03%) | 80 (24.46%) | 98 (29.97%) | 112 (34.25%) | 3.83 | 1.11 |
| High initial costs | 14 (4.28%) | 23 (7.03%) | 80 (24.46%) | 98 (29.97%) | 112 (34.25%) | 3.83 | 1.11 |
| **Aggregate** | | | | | | **3.81** | **1.12** |

Table 5 presents a comprehensive analysis of stakeholder perceptions regarding the barriers inhibiting the adoption of sustainable construction materials and practices within the Kenyan built environment. The findings are based on respondents' evaluations using a five-point Likert scale, ranging from 1 (Not at all) to 5 (Very great extent), enabling the quantification of perceived significance for each challenge. The analysis reveals that all nine assessed factors were considered moderate to very significant inhibitors, with mean scores exceeding 3.6, thereby underscoring the systemic nature of the barriers across the sector.

The lack of appropriate skills and technical knowledge for sustainable construction emerged as one of the most critical barriers. With only 2.45% of respondents perceiving, it as not a barrier and 3.36% indicating it to be of little extent, the overwhelming majority (94.29%) acknowledged it as a moderate to very significant challenge. The high mean score of 4.01 and relatively low standard deviation of 0.95 indicate a strong consensus that capacity gaps, particularly in generating specifications for alternative materials, undermine adoption efforts. This result aligns directly with the study objective by highlighting the necessity of human capital development as a foundation for advancing sustainability in construction.

Similarly, regulatory hurdles, especially difficulties in obtaining approvals for new technologies and uncertainties in building code compliance, were identified as substantial obstacles. A combined 65.44% of respondents rated this challenge as having a great or very great impact, yielding a mean score of 3.86 and a standard deviation of 1.08. While slightly more variable than the skills gap issue, this reflects a widespread perception that bureaucratic inertia and outdated regulatory frameworks inhibit innovation. The hesitation to integrate modern materials within existing codes slows the pace of sustainable development and disincentivizes experimentation.

Conflicting building codes also emerged as a significant regulatory bottleneck. While 3.36% and 6.12% of respondents dismissed it as negligible, a majority of over 90% considered it a moderate to very serious barrier. With a mean of 3.86 and a standard deviation of 1.04, the responses suggest that misalignment of standards between jurisdictions creates inconsistencies that obstruct uniform application of sustainability practices. This reinforces the systemic policy disconnect that must be addressed through harmonized regulatory reforms.

The lack of financial incentives by the government was another prominent barrier, perceived by 62.38% of respondents as significant (to a great or very great extent). The mean of 3.82 and SD of 1.06 reflect moderate consensus on the critical role that fiscal policy plays in stimulating adoption. These findings imply that without tangible economic drivers such as subsidies, tax reliefs, or grants, the private sector may lack sufficient motivation to transition toward greener alternatives, particularly in cost-sensitive construction environments.

Closely linked to both regulatory and financial challenges is the uncertainty surrounding the performance of sustainable materials. This barrier was rated significantly by 63% of respondents, resulting in a mean score of 3.80 and SD of 1.10. Such uncertainty may arise due to a lack of demonstrative case studies, performance benchmarks, or reliable certifications. Stakeholders appear hesitant to adopt materials perceived as untested or inconsistent, especially when durability and safety are at stake. This underscores the pressing need for field validation, long-term pilot projects, and knowledge dissemination to boost confidence in material alternatives.

Another institutional constraint identified was the inadequate integration of sustainability in educational curricula. Approximately 84% of respondents recognized this factor as at least a moderate challenge, with 56.88% assigning it high severity. Although the mean score of 3.67 was the lowest among all items, its relatively higher standard deviation (1.20) suggests diverse exposure to sustainability training among professionals. This diversity likely reflects disparities in educational access or generational gaps in curriculum content. Nevertheless, the result clearly points to the need for reform in architectural, engineering, and construction education to embed sustainability as a core competency.

From a market perspective, low or limited demand for sustainable materials was rated with the highest mean score (4.02) and a low SD of 0.98, indicating a strong consensus on its importance. A total of 74% of respondents rated it as a great or very great barrier. This suggests that sustainable products are not yet normalized in market expectations or procurement specifications. The apparent lack of consumer and contractor demand likely stems from limited awareness, lack of trust in alternatives, or perceived cost burdens. Addressing this barrier may therefore require robust marketing, user education, and demonstration of economic returns.

The barrier of lack of belief in the perceived benefits of sustainable construction recorded the most uniform agreement among all the variables. With a high mean score of 4.13 and the lowest SD of 0.95, 77.37% of respondents rated it as a great or very great challenge. The result indicates deep-rooted skepticism among industry actors regarding the promised advantages of sustainable practices, whether environmental, economic, or operational. This underscores the need for strategic communication, impact measurement, and policy-driven pilot programs to bridge the perception gap.

High initial costs were unsurprisingly flagged as a key deterrent. While 11.62% rated this factor as having little or no effect, a commanding 67.59% indicated it to be a great or very great barrier. The mean of 3.91 and SD of 1.14 reflect significant concern over the affordability of sustainable technologies and materials, particularly in a cost-sensitive and competitive market like Kenya's construction sector. The findings imply that unless the capital cost burden is mitigated through financing options or long-term savings demonstrations, uptake may remain limited.

The data indicate that all nine challenges are perceived as moderate to severe inhibitors, with mean scores clustering near 4.0 and most standard deviations below 1.2. This pattern suggests broad consensus among construction stakeholders regarding the multifaceted nature of the barriers—ranging from technical and regulatory to financial and perceptual. The overall aggregate mean score of 3.81 and standard deviation of 1.12 further reinforce this interpretation, showing that respondents generally view the adoption of sustainable construction materials as significantly constrained, albeit with moderate variation based on role or context.

These insights directly support the study's objective by empirically validating that adoption barriers are widespread, interrelated, and context-sensitive. They also point toward priority intervention areas, such as training, policy harmonization, financial incentives, and public awareness, that must be addressed in a coordinated and systemic manner to accelerate the uptake of sustainability in Kenya's construction industry. The visual summary presented in Figure 1 complements this interpretation by synthesizing mean scores across all variables for comparative emphasis.

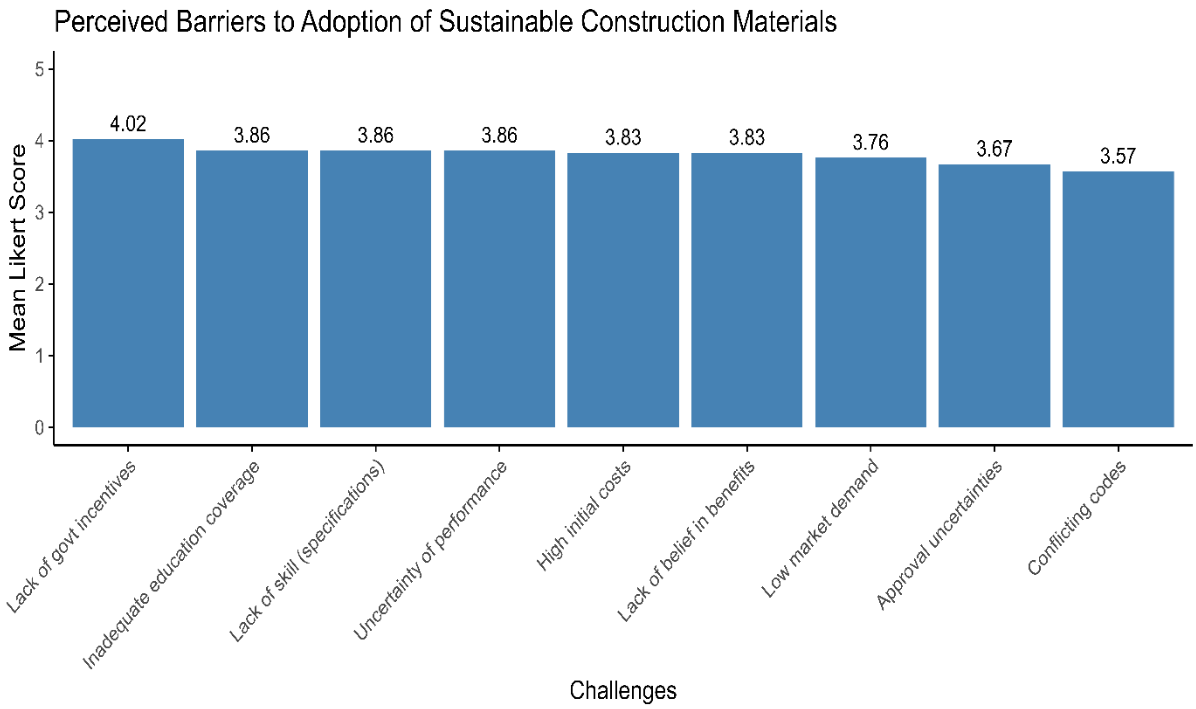


Figure 1: Perceived barrier to adoption of sustainable construction materials.

### 4.3 Discussion

The Industrial Ecology Theory, which underpins the study's conceptual orientation, argues that construction systems should mirror ecological systems in promoting resource efficiency, circularity, and inter-sectoral integration. However, the results in Section 4.3 reveal that the Kenyan construction sector remains far from operationalizing these principles due to entrenched structural and institutional barriers. A key outcome from Section 4.3 was the identification of inadequate technical skills and deficient knowledge in sustainable construction methods as a significant constraint, evidenced by a high mean score of 4.01. Industrial Ecology Theory emphasizes life-cycle thinking and systems-level innovation, both of which are unattainable without a workforce equipped with specialized knowledge. This deficiency in technical capacity, particularly in producing specifications for alternative materials, aligns with the theoretical insight that knowledge bottlenecks, data scarcity, and poor interdisciplinary training obstruct sustainability transitions. Therefore, the strong consensus on skills-related barriers among respondents empirically validates the theory's proposition that human capital development is foundational to systemic transformation.

Further, challenges such as regulatory uncertainty, conflicting building codes, and the difficulty of gaining approval for new technologies collectively echo the theoretical framework's focus on institutional silos and fragmented governance. Industrial Ecology highlights the need for cross-sector collaboration and policy integration, which is absent in the Kenyan context as illustrated by the high mean scores (ranging between 3.57 to 3.86) attributed to these regulatory obstacles. These findings correspond to empirical studies like [20] and [21], which identified regulatory voids and policy misalignment as dominant impediments to sustainable practices. In particular, [20] emphasized that despite the potential for material reuse through building deconstruction, the lack of standard design regulations and technical guidance remains a major hindrance—an observation that mirrors the Kenyan respondents' concerns about building code inconsistencies and bureaucratic inertia.

The empirical review in Section 2.2 also underscores the financial dimension of sustainability barriers. In Section 4.3, the lack of financial incentives by government received a high mean score of 4.02, confirming [21]'s argument regarding the green finance gap. According to the reviewed literature, risk-averse financial institutions and absent policy frameworks inhibit access to financing for green construction. The respondents' emphasis on economic disincentives suggests that without proactive government support—through subsidies, tax relief, or other incentives—the private sector lacks the impetus to adopt costlier but environmentally beneficial alternatives. This observation also reflects the Industrial Ecology view that market readiness must be supported by institutional enablers.

Concerns regarding the uncertainty of material performance (mean = 3.86) reflect another dimension of both theoretical and empirical concern. Industrial Ecology Theory stresses the importance of material circularity and lifecycle performance, which rely on verifiable data and predictable outcomes. Yet, the empirical results indicate that stakeholders remain skeptical due to the absence of reliable benchmarks or certification systems. Similarly, empirical literature, such as [5], reports a limited application of lifecycle assessment (LCA) models in developing contexts, making it difficult to compare the durability, cost, and environmental trade-offs of sustainable versus conventional materials. This lack of performance data and real-world testing reinforces the notion that without clear standards and proven case studies, sustainable materials will continue to face market resistance.

Educational deficiencies, as captured in the finding on inadequate curriculum coverage, also intersect directly with theoretical propositions. A mean score of 3.67, though comparatively lower, still signals significant concern. The Industrial Ecology approach promotes the diffusion of sustainability values across disciplines and professions. However, as [22] and [23] argue, technical readiness and institutional alignment—including in higher education—remain underdeveloped, limiting the broader cultural and technical acceptance of sustainability in construction. The observed variability in responses, as indicated by a higher standard deviation (1.2), may suggest differing exposure levels among professionals, further underscoring the fragmented nature of sustainability education in Kenya.

Market-related factors also received strong confirmation in Section 4.3. The perception of low or limited demand for sustainable materials (mean = 4.02) and the lack of belief in their benefits (mean = 4.13) were among the highest-rated barriers. These align with Industrial Ecology's concern about cultural resistance and market inertia. Despite technological readiness or policy support, if end-users and contractors remain unconvinced of the tangible value of sustainable solutions, uptake will stagnate. [21] and [5] likewise note that awareness campaigns and user engagement are crucial components often overlooked in sustainability transitions. Without demonstrable success stories and clear economic benefits, skepticism and risk aversion will continue to dominate market behavior.

The issue of high initial costs (mean = 3.91) remains a cross-cutting challenge that ties together several of the above dimensions, economic, institutional, and perceptual. While Industrial Ecology envisions long-term gains through closed-loop systems and reduced lifecycle costs, these benefits are often not immediately visible to builders or developers operating in highly competitive environments. This observation aligns with [21] finding that many developers lack access to tailored financing models, making the upfront costs of sustainable options appear prohibitive despite downstream advantages.

These findings hold critical policy and strategic relevance. The need for targeted capacity-building programs is clear. Professional training, vocational education, and university curricula must be updated to include sustainable construction modules grounded in practical application and material innovation. Regulatory reform is urgent such as harmonized codes, streamlined approval processes, and enforceable standards are essential to reduce uncertainty and facilitate innovation. The government must step in as a catalyst, providing fiscal incentives, establishing demonstration projects, and de-risking sustainable investments through public-private partnerships. Awareness and behavior-change campaigns are needed to shift market perceptions and normalize the use of sustainable materials. Cross-sector collaboration, between regulators, industry, academia, and civil society, must be institutionalized to overcome fragmentation and align interests around shared sustainability goals. The study reaffirms that barriers to sustainability in the built environment are not isolated or incidental, but systemic and multidimensional, requiring coordinated, evidence-based, and inclusive interventions to overcome.

## 5. CONCLUSION

This study sought to examine the inhibiting factors affecting the adoption of sustainable construction materials and practices within the Kenyan built environment. Drawing on both theoretical foundations such as the Industrial Ecology Framework and empirical reviews from global and local contexts, the study systematically analyzed stakeholder perceptions using structured questionnaires and descriptive statistics. The findings reveal that while sustainable construction is increasingly recognized as essential for environmental and socio-economic resilience, multiple interrelated barriers continue to undermine its uptake.

A critical insight from the study is the overarching influence of capacity gaps in the sector. The lack of appropriate skills and technical knowledge, particularly regarding the formulation of specifications for alternative materials, emerged as a dominant barrier. This affirms the need for targeted human capital development through revised academic curricula, professional training, and upskilling programs. Additionally, regulatory and institutional weaknesses—including difficulties in obtaining approvals, conflicting building codes, and limited policy coherence, were shown to significantly constrain innovation and discourage investment in green construction alternatives. These barriers reinforce the theoretical proposition that sustainability transitions are contingent not only on technological readiness but also on enabling institutions.

Economic challenges such as the absence of government financial incentives and the high initial cost of sustainable materials also featured prominently. The findings indicate that without adequate fiscal policy support and accessible green financing instruments, stakeholders are unlikely to voluntarily absorb the higher upfront costs associated with sustainable construction. Compounding these issues is the widespread skepticism about the actual benefits of sustainable materials and the lack of performance data, which continues to deter adoption.

The analysis further revealed a general consensus among respondents, as reflected in the high aggregate mean score (3.81) and relatively moderate standard deviation (1.12), suggesting that the listed challenges are perceived to be significant across the sector. This widespread agreement highlights the systemic nature of the problem and the urgent need for coordinated action across government, industry, academia, and civil society.

### 5.1 Limitations of the Study

Despite the robustness of the findings, the study is not without limitations. The research relied on self-reported perceptions using structured questionnaires, which may be subject to respondent bias or overrepresentation of dominant stakeholder views. The study focused primarily on professionals within urban and peri-urban areas, potentially overlooking rural perspectives and localized constraints where sustainable practices might differ significantly. While the Likert-scale approach allowed for quantification of perceptions, it did not provide in-depth qualitative insights that could have enriched understanding of the detailed experiences and institutional dynamics affecting sustainable construction adoption.

The study did not undertake a comparative analysis of existing sustainable versus conventional construction projects in Kenya, which could have provided practical benchmarks and case-specific evaluations of success and failure. The cross-sectional nature of the study limits the ability to capture evolving trends or temporal changes in perception over time.

### 5.2 Recommendations

Institutions of higher learning and professional bodies should reform curricula and expand continuing professional development programs to strengthen technical capacity in sustainable construction. The government, through agencies such as NCA and KEBS, should harmonize building codes and streamline approval processes for green technologies. Fiscal incentives such as tax reliefs and green loans are essential to reduce adoption costs, while public-private partnerships can promote demonstrative projects. Awareness campaigns and evidence-based advocacy should counter skepticism, and inclusive, context-sensitive policies must address rural and informal sectors.

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