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Status and Impact of Sustainable Construction Materials and Practices Utilization in the Built Environment in Kenya

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Abstract

The construction industry in Kenya faces a growing imperative to align with global sustainability targets by adopting environmentally responsible materials and practices. This study investigates the current status and perceived impact of sustainable construction materials and practices in Kenya's built environment. Using a quantitative research approach, data were collected through a structured questionnaire administered to 439 respondents from a diverse group of professionals, including engineers, architects, quantity surveyors, project managers, contractors, and developers. The study employed descriptive statistics and Likert scale analysis via R software to assess the extent of utilization and the influence of sustainability on economic, social, and environmental dimensions. Findings reveal a selective and uneven adoption of sustainable construction methods. Practices such as regionally appropriate materials, active solar technologies, and passive building designs recorded higher adoption levels, while low-tech or unfamiliar materials such as straw bales and fly ash exhibited significantly low uptake. Impact assessment results demonstrated strong perceived benefits, with high mean scores across dimensions like energy conservation (mean = 4.20), durability (mean = 4.01), comfort (mean = 4.13), and waste reduction (mean = 4.00). The aggregate impact mean score of 3.94 indicates a generally favorable perception of sustainability's role in transforming the built environment. Despite this optimism, the study also highlights critical challenges, including limited policy enforcement, technical capacity gaps, and inconsistent stakeholder engagement. The paper concludes that, while awareness and selective application of sustainable practices are increasing, a more coherent national strategy is required to ensure systematic uptake. The findings offer valuable implications for policymakers, educators, and industry leaders seeking to mainstream sustainable construction in Kenya.

Keywords

Sustainable Construction, Kenya, Built Environment, Adoption, Impact Assessment, Construction Materials, Energy Efficiency, Policy, Stakeholder Engagement

1. Introduction

The global pursuit of sustainable development has increasingly emphasized the construction industry's critical role in shaping a built environment that supports environmental stewardship, economic resilience, and social equity [1]. The escalating ecological degradation, resource depletion, and mounting carbon emissions associated with conventional building practices have catalyzed a paradigm shift towards sustainable construction materials and methodologies [2]. Cement production alone is responsible for approximately 7% - 8% of global CO_2 emissions, with direct process emissions estimated at 1.50 ± 0.12 gigatonnes (Gt) in 2018, largely due to the calcination of limestone and the combustion of fossil fuels in clinker production [3]. Internationally, the construction sector consumes between 30% - 40% of total energy and generates nearly 40% of carbon emissions, encompassing both operational and embodied energy demands [4]. These figures emphasize the urgent need for transformative interventions that align with international climate goals, particularly those outlined in the Paris Agreement, and that promote sustainable urbanization through the adoption of low-carbon technologies, circular economy principles, and resilient building practices.

In Kenya, these concerns are magnified by rapid urbanization, population growth, and rural-to-urban migration, which exert immense pressure on natural resources, infrastructure, and housing systems [5]. As a result, urban centers face a host of environmental challenges, including increased waste generation, air and water pollution, and rising energy demands. The situation calls for a deliberate and structured adoption of sustainable construction practices that mitigate the negative environmental impact of the built environment while promoting long-term socio-economic benefits. Yet, despite increased awareness, the utilization of sustainable construction materials and practices in Kenya remains at a nascent stage, constrained by economic, technical, regulatory, and behavioral barriers.

At the heart of sustainable construction lies the principle of reducing the environmental footprint of buildings throughout their life cycle, from design and construction to operation, maintenance, and eventual deconstruction. This encompasses not only the choice of materials but also energy use, water efficiency, waste management, and indoor environmental quality. Green buildings (GBs), as a manifestation of sustainable development, are designed to eliminate or significantly reduce negative environmental impacts while enhancing the health and well-being of occupants and improving operational cost efficiency [6]. The integration of circular economy principles, including reuse, recycling, and resource efficiency, forms a core pillar of this approach.

One of the central concerns in sustainable construction is the type and source of materials used. Traditional construction materials such as Portland cement and natural aggregates have high embodied energy and contribute significantly to greenhouse gas emissions [7]. For instance, cement alone is responsible for approximately 5% of global CO_2 emissions, and concrete production constitutes around 75% of construction waste at the end of a building's life cycle. In Kenya, the widespread use of non-renewable and environmentally burdensome materials underscores the urgency to explore alternatives. The adoption of recycled aggregates, agricultural waste-based binders, geopolymeric bricks, and locally sourced eco-friendly materials could offer practical solutions to mitigate the environmental impacts of construction while reducing costs and dependency on imported inputs.

Furthermore, the utilization of sustainable construction materials in Kenya must be examined not only in terms of environmental performance but also in relation to economic feasibility, social acceptability, and technological adaptability. The construction industry must transition from a linear resource consumption model to one that mirrors natural ecosystems—cyclical, regenerative, and resilient [8]. Construction ecology emphasizes designing systems where waste from one process becomes input for another, thereby promoting a metabolism that aligns with sustainable resource management. Such a transformation necessitates systemic change, including design for deconstruction, modular building components, and improved building life cycle assessments (LCA).

Kenya's journey towards sustainable construction is further complicated by institutional and policy shortcomings. While policies such as the National Climate Change Action Plan and the Green Economy Strategy and Implementation Plan articulate the country's commitment to sustainability, their enforcement remains weak. The lack of mandatory green building codes, limited incentives for eco-innovation, and fragmented coordination among stakeholders pose significant obstacles to progress. In contrast, successful models from other regions, such as the implementation of Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM) certifications, underscore the importance of standardized frameworks and performance benchmarks in driving sustainable construction.

Equally critical is the behavioral dimension of sustainability. Public perception, awareness, and acceptance play a pivotal role in the uptake of sustainable building practices. [6] observes that despite the long-term benefits of green buildings, public adoption remains low due to limited dissemination of information, perceived high costs, and unfamiliarity with green technologies. In Kenya, this challenge is exacerbated by limited capacity building among architects, engineers, and construction professionals, resulting in a skills gap that hinders the design and execution of sustainable projects. Thus, educational initiatives, stakeholder training, and community engagement are vital in bridging knowledge gaps and fostering a culture of sustainability in the built environment.

Moreover, an understanding of the socio-economic implications of sustainable construction is indispensable. In a developing country like Kenya, sustainability must be pursued in a way that advances economic inclusion, affordability, and access to housing [9]. The utilization of locally available materials, such as bamboo, stabilized earth blocks, and recycled aggregates, not only reduces environmental impact but also creates employment opportunities and supports local economies. Additionally, sustainable construction can enhance resilience to climate change by reducing vulnerability to heat stress, flooding, and resource scarcity, issues that are increasingly affecting urban and rural populations alike.

From an operational standpoint, the incorporation of energy-efficient systems, natural ventilation, water conservation measures, and passive solar design can drastically improve building performance while lowering operational costs [10]. As evidenced in other global contexts, passive houses and zero-energy buildings (ZEBs) can achieve up to 90% energy savings compared to conventional structures, contributing to national goals of carbon neutrality and energy security. In Kenya, where energy access and affordability remain critical development issues, sustainable building practices can offer dual benefits: environmental protection and improved quality of life. The sustainable construction landscape in Kenya is characterized by both significant potential and formidable challenges. The sector must navigate complex interplays between environmental sustainability, economic viability, social equity, and technical capacity. Drawing from global best practices and contextualizing them within Kenya's unique socio-economic and ecological landscape offers a strategic pathway to enhancing the status and impact of sustainable construction materials and practices. By fostering multi-sectoral collaboration, strengthening regulatory frameworks, incentivizing innovation, and empowering communities, Kenya can reposition its construction sector as a catalyst for sustainable development and climate resilience.

2. Literature Review

2.1. Theoretical Review

Sustainable construction, as a multidisciplinary domain, is supported by several theoretical models that seek to guide the evaluation and implementation of environmentally responsible, socially responsive, and economically viable practices. Among the most influential and technically grounded frameworks are Industrial Ecology and Construction Metabolism, and the Triple Bottom Line (TBL) and Sustainable Development Model.

2.1.1. Industrial Ecology

Industrial Ecology (IE) offers a systems-oriented approach to understanding how industrial activities, including construction, can emulate the cyclical and resource-efficient behavior observed in natural ecosystems [11]. Rooted in ecological science and systems engineering, industrial ecology seeks to minimize waste, optimize resource use, and close the loop in material and energy flows. [8] extended this model into what they term Construction Ecology and Construction Metabolism, providing a specialized lens through which to analyze material throughput in the construction industry. Construction metabolism refers to the quantification and management of energy and material flows within construction processes, from raw material extraction to building operation and eventual demolition. This concept aligns closely with LCA, which examines the environmental burdens associated with all stages of a product or process. Within the construction context, this includes embodied energy, emissions, transport distances, and waste management.

The application of industrial ecology in construction encourages the adoption of reuse and recycling principles, the minimization of virgin resource extraction, and the design of structures that are modular, adaptable, and easy to disassemble [12]. For example, concrete recycling, utilization of supplementary cementitious materials like fly ash or rice husk ash, and prefabricated building systems all stem from this theoretical foundation. In Kenya, where urban growth is accelerating and infrastructure expansion is a national priority, construction metabolism offers a framework for tracking resource consumption trends and identifying intervention points to improve sustainability. This approach is especially relevant in urban centers such as Nairobi, Kisumu, and Mombasa, where construction is a major contributor to environmental degradation due to its linear use of materials and high dependency on cement and imported products.

2.1.2. Triple Bottom Line

The Triple Bottom Line (TBL) model integrates environmental, economic, and social dimensions into a unified sustainability paradigm [13]. TBL emerged from the field of corporate social responsibility but has since been widely adopted in the built environment to assess the performance of green buildings and sustainable urban development. In this model, sustainability is achieved when projects and policies yield net-positive outcomes across all three domains: they must minimize environmental degradation, provide economic viability, and ensure social well-being and equity. The framework is particularly useful for evaluating the long-term impacts of building materials and design choices, as it accommodates both quantitative metrics (such as carbon emissions and cost-benefit ratios) and qualitative aspects (such as occupant comfort, health, and inclusivity).

The TBL framework underpins numerous green building certification systems globally, including LEED, BREEAM, and the Green Star rating system [14] [15]. These tools use TBL-derived criteria to assess factors such as energy efficiency, indoor environmental quality, site sustainability, water efficiency, and material use. In practical terms, this translates to the promotion of passive design strategies, the use of low-emission materials, and investment in renewable energy systems. Technically, it also requires the integration of LCC to determine not just initial capital costs, but the total cost of ownership over a building's lifespan.

Applying this framework to Kenya's built environment context highlights both challenges and opportunities. While the environmental component is addressed in national frameworks such as the National Climate Change Action Plan (NCCAP) and Vision 2030, economic and social sustainability often remain underexplored. For example, the high upfront cost of sustainable materials deters adoption despite potential long-term savings, while affordable green housing remains limited. Moreover, there is often insufficient attention to the social component of sustainability, particularly regarding equitable access to safe, healthy housing and infrastructure. The TBL model thus provides a holistic and contextually adaptable lens through which Kenya can evaluate the full impacts of its construction strategies and material choices.

IE and TBL frameworks offer a robust theoretical foundation for assessing and advancing sustainable construction in Kenya. While industrial ecology helps stakeholders understand how resources are consumed and managed, the TBL framework provides clarity on why sustainability matters across interconnected domains. Their integration could inform policy formulation, curriculum development in architectural and engineering education, and the refinement of Kenya's green building codes and procurement practices. As Kenya continues to urbanize and invest in infrastructure, grounding its construction activities in these frameworks will be essential for achieving long-term sustainability, economic competitiveness, and social equity in the built environment.

2.2. Empirical Review

The transition toward sustainable construction practices has been widely endorsed across global contexts, yet practical implementation continues to lag, largely due to structural, institutional, and behavioral barriers. The literature offers a multidimensional understanding of the status and impact of sustainable construction materials and practices, highlighting the interplay between governance, technology, market actors, and end-user behavior.

As [16] observed in the Australian context, the uptake of sustainability in construction has been hampered not by a lack of technologies or policies but by a fragmented governance landscape and weak stakeholder engagement. This sentiment is echoed by [17], who argue that collaboration, particularly between designers and contractors, is essential to bridge the gap between theoretical energy performance and real-world outcomes. Both studies point to a key limitation of current approaches: technical solutions alone are insufficient. What is required is an ecosystem of aligned incentives, awareness, and stakeholder collaboration that cuts across the entire construction value chain.

This perspective is reinforced by [18], who examined group self-build housing in the UK and found that community-driven models not only improved sustainability outcomes but also enhanced social cohesion and knowledge transfer among participants. Their findings suggest that sustainable construction is not merely a function of materials and technologies but also of social innovation and empowerment. The transformative power of involving end-users and communities in the building process presents a critical counterpoint to technocratic models of sustainability.

Complementing this social dimension, [19] shifted the focus to "middle actors" in the supply chain, such as manufacturers and merchants, revealing that these often-overlooked players can drive sustainable practices through influence on both demand and supply. In contrast to the dominant narrative that places regulatory authorities and developers at the center of sustainability transitions, their study contends that market intermediaries play a crucial role, particularly in the retrofit and repair sectors. This finding aligns with the broader argument across the literature that sustainable construction is a multi-actor endeavor that cannot be centrally imposed but must be co-produced.

On the impact side, empirical evidence substantiates the tangible benefits of sustainable construction practices—environmental, social, and economic. [20], for instance, demonstrated through a robust quantitative study in Ghana that the adoption of project management tools and integrated technologies such as BIM and LEED significantly influenced the uptake of sustainable practices. However, they also emphasized that the behavioral readiness and cultural orientation of industry stakeholders serve as important mediators. This illustrates a recurring theme across the literature: technology must be embedded in a culture of sustainability to be effective.

[21] further problematized the situation in developing countries by highlighting systemic barriers such as high initial costs, lack of awareness, and weak regulatory enforcement. These barriers create a vicious cycle where sustainability remains aspirational rather than operational. Unlike [21]'s more optimistic take on technology and management tools, [21] argue that unless institutional support and financial mechanisms are in place, even the best-intentioned professionals will struggle to implement sustainable materials.

On the environmental, [22] provided strong empirical backing to demonstrate that sustainable materials such as recycled concrete, bamboo, and low-emission insulation can drastically reduce embodied carbon emissions. The study underscores the critical role of material selection in mitigating climate change, reinforcing the call by other scholars for the integration of LCA tools into regulatory frameworks and design processes. However, the practical adoption of such tools remains limited, especially in markets where immediate cost concerns outweigh long-term environmental benefits, a tension also noted by [21] in the Ghanaian.

While environmental impacts dominate many sustainability discussions, [23] introduced a vital but often overlooked dimension: social sustainability. His work shows that material choices impact not only energy and emissions but also community well-being, health, and economic inclusivity. This shifts the conversation from sustainability as a purely technical exercise to a holistic framework that integrates local culture, affordability, and health equity into material assessment and selection.

[24] explored the views of alternative building technologies (ABT) experts and end users on the drivers, barriers, and strategies for SBT adoption. Using focus group discussions and convenience sampling, qualitative data were collected and analyzed with NVivo 11. The findings show SBTs are seen as sustainable, affordable, and resilient, with strong job creation potential. The study concludes that public awareness, city-wide prototypes, and professional training are vital for wider adoption and implementation success.

[25] study addressed the limited uptake of green building practices (GBP) in Africa by systematically reviewing implementation challenges across selected countries. A total of 38 peer-reviewed articles were analyzed from databases including Scopus and Web of Science, covering five African regions. The review identified 18 key barriers, such as poor regulatory frameworks, low awareness, and inadequate financial support, and 18 potential drivers grouped into six sub-themes. The findings highlight the need for stronger policies, education, and stakeholder engagement. The study concludes that targeted, region-specific interventions are essential to promote sustainable construction practices and improve the impact of GBP across the continent.

Taken together, the literature makes a compelling case that the status and impact of sustainable construction practices are shaped by a confluence of technical, social, economic, and institutional factors. Efforts to scale sustainable construction cannot rely solely on innovation in materials or the imposition of regulations. Instead, they require systemic transformations involving stakeholder alignment, market restructuring, and cultural change. Governmental leadership, public-private partnerships, user engagement, and inclusive design must be part of an integrated approach that recognizes sustainability not as a static goal, but as a dynamic process of negotiation and co-evolution.

2.3. Contribution

The study makes a significant empirical contribution by providing a detailed, evidence-based mapping of the adoption rates of a wide array of sustainable construction materials and practices within the Kenyan built environment. Through the use of a Likert-scale survey administered to a diverse professional sample, the study captures detailed data on which practices, such as regionally appropriate building materials, active solar technologies, and passive design, are most commonly used, and which, like straw bales and fly ash, remain underutilized. This contribution is particularly important because it helps bridge the gap between policy intent and on-ground implementation by identifying which materials and practices are gaining traction, and which require targeted intervention for greater uptake. No previous study in Kenya has systematically categorized and compared adoption levels across such a broad spectrum of sustainable construction strategies.

A second major contribution of the paper lies in its comprehensive impact assessment framework, which evaluates the effects of sustainable construction practices across three dimensions: economic, social, and environmental. Using mean and standard deviation analysis, the study provides quantified insights into how sustainability influences outcomes such as durability, energy conservation, indoor comfort, and job creation. This multidimensional approach moves beyond general advocacy for sustainability by demonstrating, through respondent consensus, that sustainable practices yield measurable benefits across the entire lifecycle of construction, from operational cost reduction to climate change mitigation and enhanced occupant well-being. This offers a valuable benchmarking model for future sustainability performance evaluations in Kenya and similar developing economies.

The third contribution is the generation of actionable insights for policy and regulatory reform. By revealing inconsistencies in adoption (such as low uptake of circular and zero-energy construction despite proven benefits) and highlighting gaps in stakeholder awareness, training, and coordination, the paper underscores the need for a national framework to support sustainable construction. These findings are critical for informing government agencies, regulators, professional bodies, and educational institutions on where to focus capacity-building, policy incentives, and curriculum updates. Furthermore, the study's linkage to global literature provides a grounded comparative perspective, reinforcing its relevance and transferability to broader contexts within the Global South.

2.4. Definition of Terms

Natural or locally available materials refer to inputs like earth, bamboo, or stone that reduce transport energy and support regional sustainability. Recycled-content materials include reused components such as fly ash and recycled concrete. Renewable energy technologies harness sources like solar power through active and passive systems. Concrete innovation strategies involve alternatives such as self-compacting or geopolymer concrete to enhance efficiency and reduce emissions. Green building design systems encompass features like zero-energy buildings, cool roofs, and modular layouts that lower environmental impact. Circular construction is a resource-efficient approach that promotes material reuse, recycling, and design for disassembly to minimize waste and extend material life cycles. Zero-energy buildings are highly efficient structures that generate as much energy as they consume annually, typically through on-site renewable systems like solar panels combined with passive design strategies.

3. Methodology

This study aimed to assess the status and impact of sustainable construction materials and practices in the built environment of Kenya. The research adopted a quantitative descriptive survey design, supported by qualitative insights from structured interviews. The methodology encompassed questionnaire development, sampling and data collection, data entry and cleaning, and statistical analysis using R programming.

3.1. Questionnaire Design

The questionnaire, the instrument, was carefully designed based on an extensive literature review and aligned with the study objectives. It comprised nine main sections, ranging from respondent background (items 1 - 3), material and practice adoption (items 4 - 5), and impact assessment (item 6). Most questions were constructed using 5-point Likert scales to quantify perceptions, levels of adoption, and extent of impact. The questionnaire also included multiple-response checklists for material types and open-ended sections for "others (specify)" to allow flexibility and richness of responses.

3.2. Sampling and Data Collection

Participants were selected using purposive sampling, targeting professionals within the construction industry, including architects, engineers, contractors, developers, project managers, and quantity surveyors. The rationale for this sampling method was to ensure expert-level insights from individuals directly engaged in planning, execution, or policy of construction practices. The researcher distributed self-administered electronic and physical questionnaires to over 500 participants across major cities and counties in Kenya, achieving a final valid sample of 439 respondents, yielding an exact response rate of approximately 87.8%. This high response rate enhances the reliability of the findings and reduces the likelihood of non-response bias.

The study employed a purposive sampling strategy, targeting professionals actively involved in Kenya's construction industry, including architects, engineers, project managers, contractors, quantity surveyors, and developers, to ensure the collection of expert-level, context-rich data directly relevant to sustainable construction practices. This deliberate selection was appropriate for the study's objectives, as it prioritized informed perspectives from practitioners responsible for planning, policy implementation, and on-site execution of construction projects. The use of purposive sampling introduces potential selection bias, particularly since participation was limited to individuals accessible to the researchers and may not fully represent marginalized stakeholders such as informal builders, rural actors, or community-based construction participants.

The questionnaire captured professional attributes such as occupation, years of experience, and company type (private, public, NGO), which helped contextualize the responses. The majority of respondents were experienced professionals, with 65.1% having more than 10 years of industry experience, and 53.98% drawn from private companies. This contributed to the reliability and relevance of the findings.

3.3. Data Processing and Analysis Using R

All completed questionnaires were coded and entered into Microsoft Excel, then imported into R 4.5.1 software for statistical analysis. Data cleaning was conducted using dplyr to remove duplicates, handle missing values, and convert categorical responses into numeric scales.

Descriptive statistics were computed using functions from the summary tools, psych, and base packages. Frequencies, percentages, means, and standard deviations were calculated for each item. For instance, in analyzing adoption levels, each material was summarized with the number and percentage of responses across the five Likert categories, and mean scores were calculated to indicate the central tendency of adoption.

4. Results and Discussion

4.1. Findings

The questionnaire return rate was approximately 87.8%. The questionnaire demonstrated strong internal consistency, with an average Cronbach's alpha of 0.745. This value falls within the acceptable reliability range (0.70 - 0.79), indicating that the items used to measure key variables were sufficiently consistent. As a result, the instrument is considered reliable for statistical analysis and interpretation. The reliability score supports the overall quality of the data collected, ensuring that the survey responses are dependable and reflective of underlying constructs. This level of consistency enhances confidence in the validity of the findings and supports the credibility of subsequent analysis and conclusions drawn from the study.

4.1.1. Respondents' Background Information

The researcher wanted to know about the profession of the respondents and the results are presented in **Figure 1**.

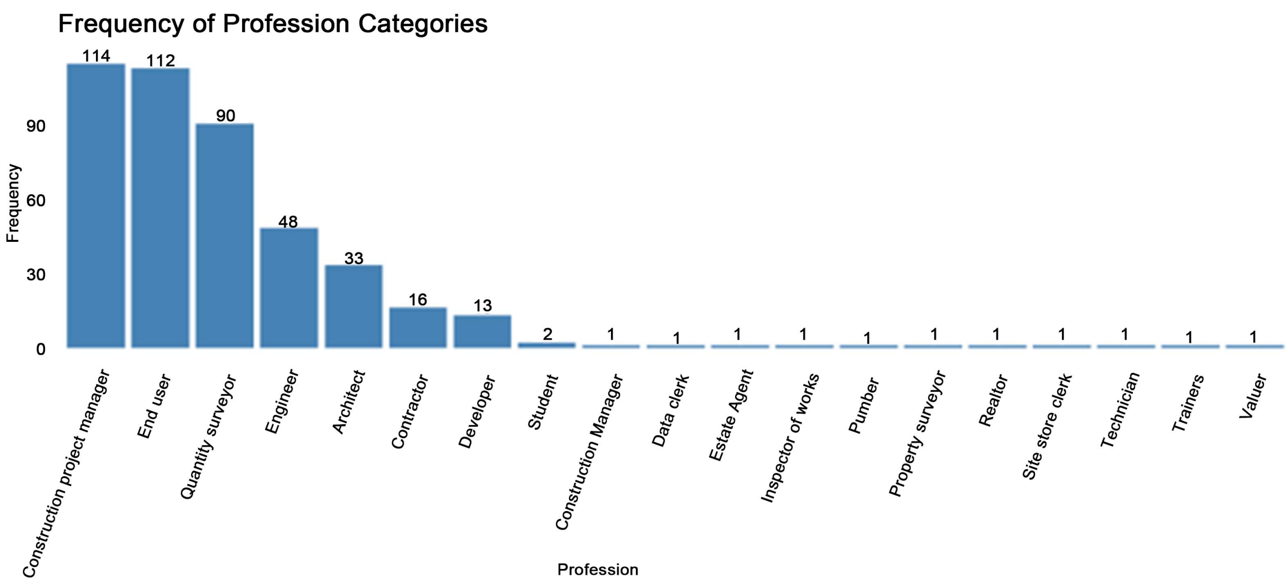

Figure 1. The distribution of respondents' professions.

Figure 1 illustrates the professional distribution of respondents involved in assessing sustainable construction materials and practices in Kenya's built environment. The data show a strong representation from core construction professionals, with Construction Project Managers (114), End Users (112), Quantity Surveyors (90), Engineers (48), and Architects (33) forming the majority. This indicates that the study captured informed perspectives from individuals with significant roles in project planning, design, costing, and execution. Additionally, Contractors (16) and Developers (13) contributed valuable insights related to on-site implementation and investment decisions, enriching the analysis with practical and financial considerations. In contrast, peripheral roles such as students, data clerks, estate agents, plumbers, and others were minimally represented, each by one or two participants. While these roles are part of the wider construction ecosystem, their limited input suggests that grassroots challenges and operational details may not be fully captured. The study also examined the respondents' distribution by professional experience, as shown in **Figure 2**.

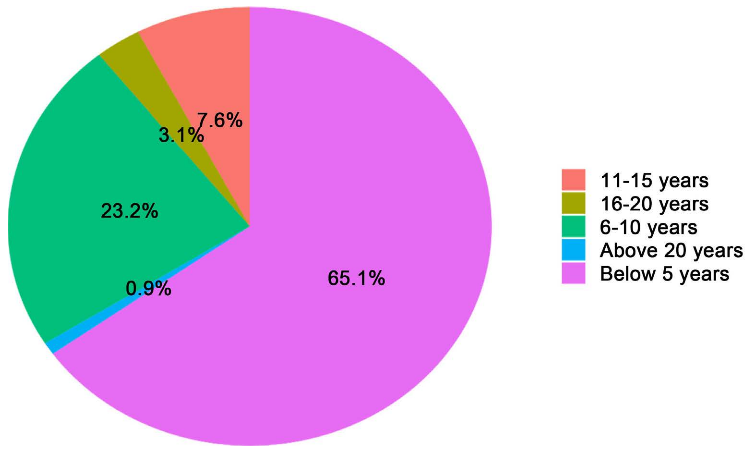

Figure 2. Distribution of respondents by professional experience.

Figure 2 shows respondents' professional experience, revealing a broad range of expertise levels that significantly influence the quality of insights provided. A substantial majority, 65.1%, had over 10 years of experience, indicating that the study primarily engaged seasoned professionals with deep familiarity with construction practices and sustainability trends. This high level of experience enhances the credibility of the findings. The next largest group, accounting for 23.2%, had 6 to 10 years of experience, reflecting individuals with strong academic and practical backgrounds. Meanwhile, respondents with 3 to 5 years and less than 3 years of experience represented 7.6% and 3.1%, respectively, introducing fresh perspectives and up-to-date knowledge, particularly in sustainable design. Only 0.9% had no experience, showing minimal input from students or early-stage learners. The data confirm that the sample was predominantly composed of experienced professionals, which strengthens the validity of the study, while the inclusion of less experienced respondents ensures that new ideas and innovations were also considered. The researcher further analyzed respondents by company affiliation, as presented in **Figure 3**.

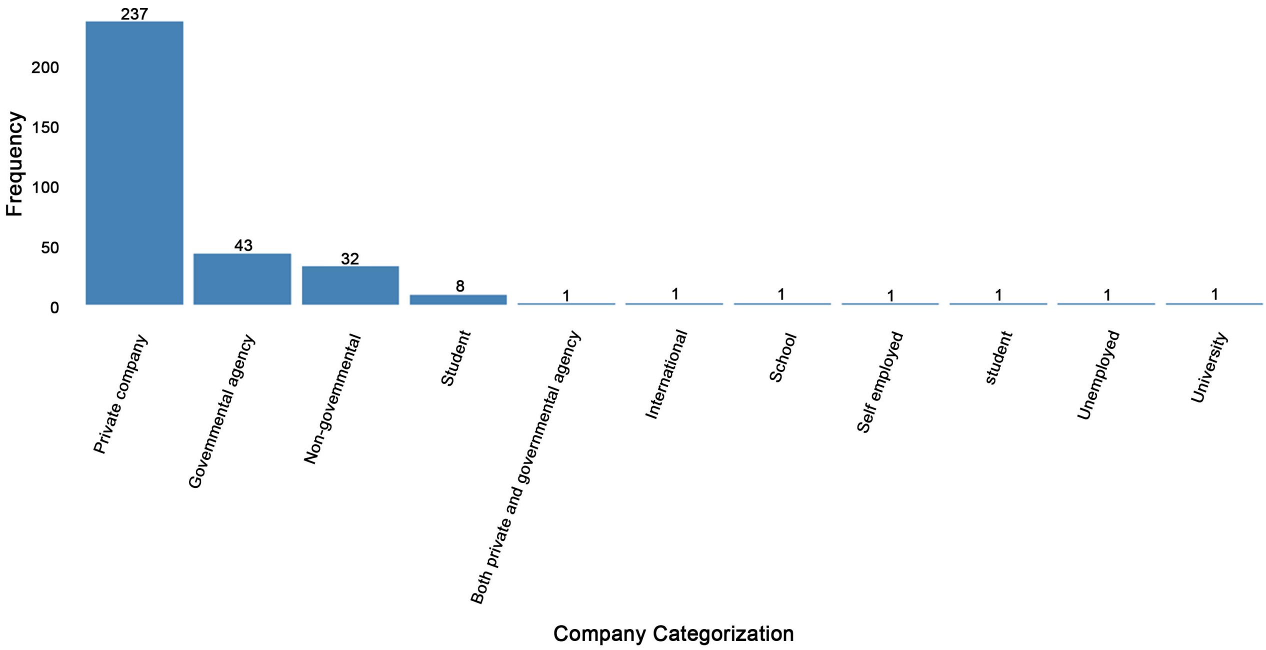

Figure 3. Distribution of respondents by their companies.

Figure 3 presents the organizational affiliation of respondents, providing insight into the institutional context influencing sustainable construction practices in Kenya. The data show that the majority, 53.98% or 237 respondents, are from private companies, highlighting the private sector's leading role in construction activities and its significant influence on the adoption or resistance to sustainable practices, driven by market dynamics and regulatory factors. Government agencies accounted for 43 respondents, while 32 were from non-governmental organizations (NGOs), offering perspectives rooted in policy implementation, enforcement, and community-based sustainability initiatives. A smaller group of 8 respondents were students, representing emerging professionals. The remaining participants, including those from international organizations, academic institutions, self-employed professionals, and unemployed individuals, each had only one representative, suggesting limited input from these sectors. Notably, one duplicate entry under "student" and a dual-affiliated respondent (private and government) were recorded, indicating minor data inconsistencies. Overall, the respondent pool is heavily skewed toward the private sector, ensuring insights aligned with current market practices. However, the limited representation from academia, international institutions, and independent actors suggests that a broader institutional mix could enrich understanding of systemic opportunities and barriers to sustainable construction in Kenya.

4.1.2. Status of Sustainable Construction Materials and Practices Utilization in the Built Environment

Respondents were presented with a variety of environmentally responsible options, including straw bales, recycled concrete aggregate, self-compacting concrete, fly ash, lime, cement-stabilized rammed earth, lean practices, green roofs, passive and active solar designs, cool roofs, zero energy buildings, circular construction, and regionally appropriate materials, to assess their usage. The results are presented in Table 1. The inclusion of "None" and "Others (Please specify)" options ensured the study captured both unadoption cases and innovative, context-specific practices not explicitly listed. This approach enabled a broad and inclusive assessment aligned with the study's objective of determining the current status of sustainable construction practices in Kenya.

The findings reveal a diverse yet uneven landscape of adoption. Regionally appropriate building materials emerged as the most commonly used, with 24 respondents (7.34%) selecting this option. This points to a preference for locally sourced, climate-sensitive, and culturally relevant materials, aligning well with sustainability goals such as reduced transport emissions and local economic support. Active solar technologies followed with 16 responses (4.89%), reflecting the increasing integration of renewable energy solutions like solar panels and heaters, consistent with national energy efficiency and off-grid initiatives.

However, 15 respondents (4.59%) indicated that they had adopted none of the listed sustainable measures, suggesting barriers such as high initial costs, lack of awareness, or reluctance to change from conventional practices. Lean construction practices and recycled concrete aggregate each garnered 10 responses (3.06%), highlighting moderate uptake of strategies that promote material efficiency and waste reduction through reuse. Self-compacting concrete received 9 responses (2.75%), signifying a growing acceptance of this method due to its benefits in enhancing construction quality and reducing labor needs. Cement-stabilized earth and green roofs, each with 7 responses (2.14%), suggest a more modest application of earth-based construction and green infrastructure features for thermal regulation and stormwater management. While a variety of sustainable materials and technologies are being used, their adoption is still developing, with usage rates varying across the sector.

Table 1. Status of sustainable construction materials and practices utilization in the built environment.

Material	Count	Percent	Cumulative Percent
Regionally appropriate building materials	24	7.34	7.34
Active solar technologies	16	4.89	12.23
None	15	4.59	16.82
Lean practices	10	3.06	19.88
Recycled concrete aggregate	10	3.06	22.94
Self-compacting concrete	9	2.75	25.69
Cement stabilized earth	7	2.14	27.83
Green roofs	7	2.14	29.97
Green roofs; Active solar technologies	6	1.83	31.80
Lime	6	1.83	33.64

Continued

Active solar technologies; regionally appropriate building materials	5	1.53	35.17
Lean practices; active solar technologies	5	1.53	36.70
Passive building design	4	1.22	37.92
Bamboo	3	0.92	38.84
Green roofs; active solar technologies; regionally appropriate building materials	3	0.92	39.76
Lime; Lean practices; Passive building design; Active solar technologies; Zero-energy buildings; Circular construction; Regionally appropriate building materials	3	0.92	40.67
Passive building design; Active solar technologies; Regionally appropriate building materials	3	0.92	41.59
Recycled concrete aggregate; Green roofs; Active solar technologies	3	0.92	42.51
Recycled concrete aggregate; Self-compacting concrete; Cement-stabilized earth	3	0.92	43.43

4.1.3. Adoption of Sustainable Construction Materials or Practices

The researcher asked the respondents to rate the extent of adoption of the sustainable construction materials or practices based on a Likert scale ranging from Very Low (1) to Very High (5). The materials and practices assessed include a broad spectrum of conventional and emerging sustainability solutions. A summary of descriptive statistics is presented in Table 2.

Table 2. Summary of adoption of the sustainable construction materials or practices.

Sustainable Materials or Practices	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)	Mean	SD
Straw bales	83 (47.16%)	42 (23.86%)	36 (20.45%)	9 (5.11%)	6 (3.41%)	1.94	1.09
Recycled concrete aggregate	37 (17.54%)	51 (24.17%)	76 (36.02%)	37 (17.54%)	10 (4.74%)	2.68	1.1
Self-compacting concrete	34 (17.44%)	40 (20.51%)	72 (36.92%)	37 (18.97%)	12 (6.15%)	2.76	1.13
Fly-ash	55 (31.98%)	59 (34.30%)	36 (20.93%)	15 (8.72%)	7 (4.07%)	2.19	1.10
Lime	22 (11.64%)	40 (21.16%)	75 (39.68%)	34 (17.99%)	18 (9.52%)	2.93	1.11
Cement-stabilized rammed earth	30 (15.31%)	41 (20.92%)	71 (36.22%)	33 (16.84%)	21 (10.71%)	2.87	1.18
Lean practices	20 (11.05%)	42 (23.20%)	68 (37.57%)	30 (16.57%)	21 (11.60%)	2.94	1.13
Green roofs	26 (13.20%)	44 (22.34%)	68 (34.52%)	37 (18.78%)	22 (11.17%)	2.92	1.17
Passive building design	20 (10.64%)	40 (21.28%)	64 (34.04%)	40 (21.28%)	24 (12.77%)	3.04	1.17

Continued

Active solar technologies	15 (6.76%)	24 (10.81%)	73 (32.88%)	59 (26.58%)	51 (22.97%)	3.48	1.15
Cool roofs	22 (12.72%)	46 (26.59%)	52 (30.06%)	34 (19.65%)	19 (10.98%)	2.90	1.18
Zero energy buildings	39 (21.55%)	49 (27.07%)	54 (29.83%)	23 (12.71%)	16 (8.84%)	2.60	1.21
Circular construction	28 (15.30%)	36 (19.67%)	63 (34.43%)	32 (17.49%)	24 (13.11%)	2.94	1.23
Regionally appropriate building materials	21 (10.61%)	33 (16.67%)	54 (27.27%)	52 (26.26%)	38 (19.19%)	3.27	1.24
Others (specify):	25 (21.74%)	25 (21.74%)	41 (35.65%)	16 (13.91%)	8 (6.96%)	2.63	1.17
Aggregate						**2.43**	**1.08**

When respondents rated the extent of adoption of various sustainable construction materials and practices using a Likert scale from "Very Low" to "Very High", the results revealed considerable variation across technologies. Straw bales had the lowest adoption, with nearly half (47.16%) rating it "Very Low" and a mean score of just 1.94, indicating limited integration likely due to structural or regulatory constraints. Recycled concrete aggregate (RCA) showed broader use, with a mean of 2.68, reflecting moderate familiarity and growing recognition of its role in circular construction, though it is still not widespread. Self-compacting concrete followed a similar trend, with moderate to high adoption levels and a mean of 2.76, attributed to its labor-saving and quality-enhancing features, especially in urban settings.

Fly ash remained underutilized, recording a low mean of 2.19 and minimal high ratings, suggesting a general lack of awareness or technical resistance despite its environmental benefits. Conversely, lime demonstrated improving acceptance (mean = 2.93), supported by its suitability in rural and low-energy construction. Cement-stabilized rammed earth also reflected growing experimentation, with a mean of 2.87, indicating interest in low-cost, thermally efficient building techniques. Lean practices scored a mean of 2.94, with considerable support for their role in minimizing waste and improving project efficiency, highlighting their alignment with both economic and environmental sustainability.

Green roofs, although moderately adopted (mean = 2.92), are valued for their aesthetic and functional contributions to urban climate resilience. Passive building design showed stronger uptake, with a mean of 3.04, indicating growing awareness of its role in energy efficiency through natural ventilation and solar orientation. Active solar technologies emerged as the most favorably adopted practice, with a high mean of 3.48, reflecting national efforts to promote renewables and reduce reliance on the electricity grid.

Cool roofs, though slightly lower in mean (2.90), were moderately accepted for their thermal efficiency benefits. Zero energy buildings (ZEBs), with a mean of

2.60, had low adoption due to high capital costs and technical demands, despite their potential for long-term sustainability. Circular construction received a mean of 2.94, suggesting growing awareness of life-cycle thinking, though still in the early stages of implementation.

Regionally appropriate building materials were among the top-rated (mean = 3.27), reflecting a strong preference for culturally and environmentally suitable solutions that reduce transportation energy and support local economies. The "Others" category, with a mean of 2.63, indicated the presence of various niche or innovative practices that are still in early stages of adoption.

The aggregate mean of 2.43 and standard deviation of 1.08 reflect moderate but uneven adoption of sustainable construction materials and practices. While technologies such as solar energy and local materials are gaining traction, others, particularly low-tech or unconventional options, remain marginalized. This pattern underscores the need for targeted interventions, including policy incentives, capacity-building, and awareness campaigns to scale up adoption. The findings affirm that sustainability is increasingly recognized within Kenya's construction sector, but its practical integration is still inconsistent, reinforcing the study's objective of mapping current usage and potential for transformation.

4.1.4. The Impact of Adopting Sustainable Construction Materials and Practices

The researcher also evaluated the impact of the adoption of sustainable construction materials and practices based on a Likert Scale: 1 = Not at all, 2 = Little extent, 3 = Moderate extent, 4 = Great extent, 5 = Very great extent.

Table 3. Impact of adopting sustainable construction materials and practices.

Impact Dimensions	Not at all (1)	Little extent (2)	Moderate extent (3)	Great extent (4)	Very great extent (5)	Mean	Standard deviation
Economic impact							
Durability	8 (2.45%)	11 (3.36%)	67 (20.49%)	126 (38.53%)	115 (35.17%)	4.01	0.95
Low operational costs	12 (3.67%)	22 (6.73%)	79 (24.16%)	100 (30.58%)	114 (34.86%)	3.86	1.08
Economy of resources/recyclability	11 (3.36%)	20 (6.12%)	76 (23.24%)	116 (35.47%)	104 (31.8%)	3.86	1.04
Overall cost reduction	8 (2.45%)	28 (8.56%)	87 (26.61%)	97 (29.66%)	107 (32.72%)	3.82	1.06
Social Impact							
Social Impact Dimensions	11 (3.36%)	30 (9.17%)	80 (24.46%)	98 (29.97%)	108 (33.03%)	3.8	1.1
Inclusive environments	21 (6.42%)	31 (9.48%)	89 (27.22%)	79 (24.16%)	107 (32.72%)	3.67	1.2

Continued

Functionality/usability	8 (2.45%)	15 (4.59%)	62 (18.96%)	121 (37.0%)	121 (37.0)	4.02	0.98
Comfortable and healthy living environment	6 (1.83%)	12 (3.67%)	56 (17.13%)	111 (33.94%)	142 (43.43%)	4.13	0.95
Job creation	15 (4.59)	23 (7.03%)	68 (20.8%)	91 (27.83%)	130 (39.76%)	3.91	1.14
Environmental Impact							
Ecosystem protection	7 (2.14%)	11 (3.36%)	67 (20.49%)	83 (25.38%)	159 (48.62%)	4.15	1
Energy conservation	5 (1.53%)	13 (3.98%)	54 (16.51%)	94 (28.75%)	161 (49.24%)	4.2	0.96
Reduced carbon footprint	9 (2.75%)	24 (7.34%)	67 (20.49%)	91 (27.83%)	136 (41.59%)	3.98	1.08
Conservation of water	14 (4.28%)	14 (4.28%)	83 (25.38%)	102 (31.19%)	114 (34.86%)	3.88	1.07
Embodied use of energy	8 (2.45%)	25 (7.65%)	84 (25.69%)	107 (32.72%)	103 (31.5%)	3.83	1.03
Waste reduction	8 (2.45)	21 (6.42%)	61 (18.65%)	110 (33.64%)	127 (38.84%)	4	1.03
Aggregate						**3.94**	**1.04**

Table 3 presents a comprehensive analysis of the perceived impact of sustainable construction materials and practices across economic, social, and environmental dimensions, using mean scores to capture central tendencies and standard deviations to reflect response variability. Economically, durability was rated highly, with a mean of 4.01 and a low SD of 0.95, indicating strong agreement that sustainability enhances building longevity and reduces long-term maintenance needs. Low operational costs and resource efficiency also scored well (mean = 3.86), reflecting widespread recognition of the long-term financial benefits of sustainable materials, though slightly higher standard deviations hint at variations in individual project experiences. Cost reduction, while the lowest in the economic category (mean = 3.82), still reflects substantial perceived benefit, tempered perhaps by the initial costs of implementing sustainable technologies.

Socially, perceptions were generally favorable but more varied. Inclusive environments received a lower mean of 3.67 and the highest SD in the social category (1.2), suggesting inconsistent application across projects. In contrast, functionality/usability achieved one of the highest social ratings (mean = 4.02, SD = 0.98), showing a strong consensus that sustainable buildings are practical and user-friendly. The highest-rated social factor was the creation of comfortable and healthy living environments (mean = 4.13, SD = 0.95), underscoring agreement on the health and well-being benefits of sustainable design. Job creation, while positively viewed (mean = 3.91), showed greater variability (SD = 1.14), indicating differences in how this benefit is realized across regions and project types.

Environmental impacts were rated most consistently and favorably. Ecosystem protection (mean = 4.15), energy conservation (mean = 4.20), and waste reduction (mean = 4.00) were all strongly endorsed, highlighting the ecological value of sustainable practices such as low-impact construction, renewable energy use, and material recycling. Energy conservation, in particular, emerged as the top-rated impact, with a mean of 4.20 and a low SD of 0.96, reflecting broad consensus on its effectiveness. Other areas such as reduced carbon footprint (mean = 3.98), water conservation (mean = 3.88), and embodied energy use (mean = 3.83) also demonstrated significant perceived impact, though with some variation, likely due to differing levels of awareness or project-specific application.

The analysis across all 17 impact indicators yielded an aggregate mean of 3.94, signifying that respondents generally perceive sustainable construction practices as having a strong and positive influence on the built environment. The corresponding SD of 1.04 suggests moderate consistency, with some variability influenced by stakeholder roles, experience, or organizational context. Notably, areas with slightly higher variation, such as inclusivity and job creation, highlight opportunities for more focused policy, design, and capacity-building interventions. Collectively, these findings affirm that sustainable construction is viewed as highly beneficial across multiple dimensions, aligning closely with the study's objective of evaluating its real-world impact in the Kenyan context.

4.2. Discussion

4.2.1. Status of Sustainable Construction Materials and Practices Utilization in the Built Environment

The study set out to evaluate the extent to which sustainable construction materials and practices are utilized within Kenya's built environment, using quantitative data collected via Likert-scale assessments. Results revealed significant variability in adoption levels, underscoring a fragmented uptake pattern that mirrors existing concerns in the sector about inconsistent awareness, application, and support for sustainability practices. Among the most adopted strategies were the use of regionally appropriate materials and energy-related technologies such as active solar systems and passive design solutions. Regionally appropriate materials achieved a relatively high mean score of 3.27, indicating a growing appreciation for contextually grounded construction solutions that reflect local climates, resource availability, and cultural practices. This aligns with [19], who highlighted the transformative influence of localized, bottom-up efforts led by "middle actors" such as suppliers and artisans.

Similarly, active solar technologies demonstrated a high mean score of 3.48, suggesting that solar energy is increasingly embraced, likely driven by rising grid electricity costs and unreliable supply. This reflects [18] findings that energy efficiency measures gain traction when end-users are empowered with knowledge and affordability. In contrast, some materials like straw bales (mean = 1.94) and fly ash (mean = 2.19) recorded the lowest adoption levels, with a majority of respondents indicating "Very Low" or "Low" usage. These findings suggest that lack of familiarity, availability, or technical guidance impedes their integration. As [16] observed, the low uptake of proven sustainable solutions in developing countries often stems from systemic barriers such as insufficient training, resistance to innovation, and lack of practical demonstration projects.

Further analysis revealed that practices within circular construction and green design, such as zero-energy buildings (mean = 2.60), modular construction (mean = 2.87), and cool roofs (mean = 2.90), remain underutilized. These practices demand a high level of interdisciplinary coordination and policy alignment, which may be lacking. [17] emphasized that without structured frameworks and coordinated incentives, the adoption of circular and low-carbon practices is difficult to scale, particularly in the Global South, where institutional capacity may be limited.

Organizing the data into five thematic categories—natural or locally available materials, recycled-content materials, renewable energy technologies, concrete innovation strategies, and green building design systems—offered deeper insight into current preferences. Natural materials like crushed stone and quarry dust showed moderate uptake, while more advanced innovations such as geopolymer cement received limited attention, pointing to hesitation in transitioning toward novel material systems. The findings suggest a broader trend: while awareness of sustainable construction is on the rise, practical implementation remains selective, favoring familiar, locally available, or visibly beneficial practices.

Crucially, materials perceived as technologically complex, unfamiliar, or capital-intensive continue to face adoption challenges, regardless of their environmental benefits. This indicates that technology alone is not the driver of sustainability; institutional support, stakeholder engagement, and cultural preparedness are equally necessary. The results confirm that adoption in Kenya is highly context-sensitive, with higher uptake where practices align with local needs, incentives, or economic feasibility. Yet, the broader integration of holistic sustainability remains constrained by weak policy frameworks, inconsistent standards, and limited technical capacity.

While Kenya has made promising strides in areas like solar energy and local material use, broader adoption of sustainable practices is hindered by a lack of systemic enablers. The study highlights the need for a national performance framework, stronger regulatory enforcement, targeted capacity building, and the integration of sustainability metrics into mainstream building codes and procurement systems. These measures are critical to institutionalizing sustainability in Kenya's construction sector and ensuring long-term, sector-wide transformation.

4.2.2. The Impact of Adopting Sustainable Construction Materials and Practices

The results presented in **Table 3** provide a multidimensional understanding of the perceived impact of sustainable construction materials and practices in Kenya's built environment, covering economic, social, and environmental aspects. With all impact indicators achieving mean scores above 3.5 and an overall aggregate mean of 3.94, the findings strongly suggest that sustainability practices are widely recognized as beneficial. These results reflect a high degree of consensus among construction professionals, although some variation exists, as seen in standard deviation values.

The economic benefits are particularly evident in indicators such as durability (mean = 4.01), low operational costs (mean = 3.86), and recyclability (mean = 3.86). These findings are consistent with [21], who emphasized that while high initial costs are a deterrent in developing contexts like Ghana, long-term savings and resource efficiency justify the adoption of sustainable materials. The current study supports this by showing that once in use, these materials contribute significantly to lifecycle cost savings and economic resilience in construction.

From a technological standpoint, the high scores for energy conservation (mean = 4.20) and reduced carbon footprint (mean = 3.98) affirm the role of sustainable construction in addressing climate change, echoing [22] LCA findings on the emission-reducing benefits of green materials. The perception of waste reduction (mean = 4.00) and ecosystem protection (mean = 4.15) further illustrates that sustainable practices are not only seen as environmentally sound but also as instrumental in supporting Kenya's ecological objectives.

Socially, the impact is also notable, with indicators such as comfortable and healthy living environments (mean = 4.13) and functionality/usability (mean = 4.02) reflecting broad agreement that sustainability improves occupant well-being. These outcomes support [23] view that low-toxicity, community-oriented construction practices enhance inclusivity and social cohesion. However, the higher variability in responses related to inclusivity (SD = 1.2) and job creation (SD = 1.14) suggests inconsistent implementation or experience across the sector, potentially due to gaps in policy guidance or unequal access to training.

The findings also resonate with [20], who found that the integration of digital technologies and project management tools significantly boosts sustainability outcomes. The high scores for both technical and social indicators in this study support the idea that well-managed, technologically integrated projects offer multifaceted benefits. Moreover, Maqbool *et al.*'s emphasis on behavioral factors is indirectly supported here, with standard deviation patterns indicating that attitudes and stakeholder readiness still influence how sustainability is perceived and implemented.

The strong mean values and moderate standard deviation of 1.04 point to a growing consensus within the Kenyan construction sector on the value of sustainable practices. However, areas of divergence, particularly in social dimensions like inclusivity, underscore the need for targeted interventions. These could include clear policy mandates, public awareness initiatives, and stakeholder training to standardize the application and amplify the impact of sustainable construction practices.

This study affirms that sustainable materials and practices are not only technically and economically viable but are increasingly recognized as essential for resilient and inclusive development. Aligning with global literature, the results highlight that for Kenya to fully realize the benefits of sustainable construction, further institutional support, policy harmonization, and professional capacity building are required to ensure consistent implementation and long-term sectoral transformation.

5. Conclusions

This study set out to assess the status of utilization and the perceived impact of sustainable construction materials and practices in Kenya's built environment. The findings confirm that while awareness of sustainability is steadily growing across the construction sector, actual adoption remains fragmented and highly context-dependent. High usage was reported for regionally appropriate materials and renewable energy technologies such as solar systems, reflecting a growing alignment with localized, energy-efficient solutions. However, other sustainable options, particularly those perceived as unfamiliar, labor-intensive, or requiring technical coordination, continue to register limited uptake, underscoring that technical merit alone does not guarantee widespread implementation.

Professionals surveyed in this study perceived sustainable construction practices as beneficial across economic, social, and environmental dimensions, with high ratings for attributes such as energy efficiency, durability, and ecosystem protection. However, the variability of responses related to social inclusion and employment creation reveals gaps in enforcement, stakeholder engagement, and capacity development. These findings echo the global literature calling for institutional reform, policy coherence, and industry-wide incentives to embed sustainability more systematically within construction systems.

Kenya stands at a strategic inflection point where sustainable construction can serve as a vehicle for addressing environmental degradation, economic inefficiencies, and social inequities. To support this transition, the study recommends the following policy actions: 1) enact a mandatory national green building code with clear sustainability benchmarks to close practice gaps, especially in underutilized areas like circular construction and zero-energy buildings; 2) introduce targeted financial incentives, such as tax rebates and expedited approvals, to accelerate the adoption of sustainable technologies and materials; and 3) institutionalize sustainability-oriented professional training and certification, ensuring built environment practitioners are adequately equipped to deliver green solutions throughout the project lifecycle.

While the study offers useful insights, it is important to note several limitations. The reliance on a purposive, self-selected sample of primarily senior professionals—many from the private sector—limits the generalizability of findings across the broader construction sector, particularly among public-sector actors, site personnel, and end users. The data are perception-based, derived from Likert-scale responses rather than verified through project audits, material flow data, or permit records, and analyzed using descriptive statistics without inferential testing. These methodological choices restrict causal inference and statistical generalization. Moreover, the cross-sectional design captures a single point in time and does not allow for trend analysis.

Future studies should incorporate triangulation methods, such as building permit audits, procurement records, or life-cycle analyses, to validate self-reported practices. The inclusion of stratified or randomized samples that encompass public sector actors, contractors, and end-users would provide a more representative picture of sector-wide behavior. Additionally, longitudinal or retrospective research capturing adoption timelines could illuminate diffusion patterns and help evaluate the impact of evolving policies or market interventions.

This study contributes to the emerging body of knowledge on sustainable construction in Sub-Saharan Africa by offering a professionally informed snapshot of current perceptions and priorities. It provides a foundation for hypothesis generation, policy dialogue, and future research, offering practical pathways to align Kenya's infrastructure development with long-term sustainability goals.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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