



Path To Sustainable Construction:

Innovation in New Material, Construction Technique and Management Practice

* **Abdussalam Shibani** 

Department Higher Institute of
Science and technology Tajoura,

Ab1732@coventry.ac.uk

³ **Nawal Gherbal** 

School of Energy Construction and
Environment, Coventry University,
UK

nawalgerbal@gmail.com

² **Michel Ghostin** 

School of Energy Construction and
Environment, Coventry University, UK

ad6526@coventry.ac.uk

⁴ **Mahmud Ahmed** 

Higher institute of science and technology
Tripoli Libya

M.ahmed@his.edu.ly

⁴ **Shakeel Ahmed Kunnummal** 

School of Energy Construction and Environment, Coventry University, UK

*Corresponding Author: * Abdussalam Shibani

Keyword

*Quantitative,
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Abstract

The role of sustainable materials, new construction techniques, and management practice in enhancing the sustainability of the construction industry is examined through rigorous quantitative analysis. The research explores the advantages of using sustainable materials in relation to environmental and economic savings, assesses the impact of innovation in construction techniques on waste reduction and energy efficiency, and analyses how sustainable management practice enhances the environmental performance of construction projects. Findings also revealed that sustainable materials highly impact organizational decision-making toward sustainability, innovative techniques have greatly enhanced the performance of projects, and sound management practices are key for promoting sustainability in training programs. This study adds value to the construction industry in that it offers empirical evidence on the integration of sustainability in construction practices. The foundation from which further research and practical applications that would help promote a better sustainable construction environment could be drawn is laid here.

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الطريق نحو البناء المستدام:

الابتكار في المواد الجديدة وتقنيات البناء وممارسات الإدارة

* عبد السلام الشيباني 

المعهد العالي للعلوم والتقنية تاجوراء

Ab1732@coventry.ac.uk

² ميشيل جوستين 

كلية الطاقة والبناء والبيئة، جامعة كوفنتري
المملكة المتحدة

ad6526@coventry.ac.uk

⁴ محمود أحمد 

المعهد العالي للعلوم والتقنية طرابلس

M.ahmed@his.edu.ly

³ نوال غيربال 

كلية الطاقة والبناء والبيئة، جامعة كوفنتري
المملكة المتحدة

nawalgerbal@gmail.com

⁵ شاكيل أحمد كونومال

كلية الطاقة والبناء والبيئة، جامعة كوفنتري - المملكة المتحدة

*الباحث المرسل:	* عبد السلام الشيباني
الكلمة المفتاحية	الملخص
كمي، مادي، مبتكر، مستدام، إدارة	يتم بحث دور المواد المستدامة وتقنيات البناء الحديثة وممارسات الإدارة في تعزيز استدامة قطاع البناء والتشييد، وذلك من خلال تحليل كمي دقيق. يستعرض البحث مزايا استخدام المواد المستدامة من حيث الوفرة البيئي والاقتصادي، ويقيم أثر الابتكار في تقنيات البناء على خفض النفقات وكفاءة الطاقة، كما يحلل كيفية تعزيز ممارسات الإدارة المستدامة للأداء البيئي لمشاريع البناء. وقد أظهرت النتائج أن المواد المستدامة تؤثر بشكل كبير على اتخاذ القرارات المؤسسية المتعلقة بالاستدامة، وأن التقنيات المبتكرة قد عززت أداء المشاريع بدرجة كبيرة، فضلاً عن أن ممارسات الإدارة السليمة تُعد ركيزة أساسية لتعزيز الاستدامة في برامج التدريب. وتُضيف هذه الدراسة قيمة على قطاع البناء والتشييد من خلال تقديم أدلة عملية وتجريبية حول دمج الاستدامة في ممارسات البناء؛ إذ تضع حجر الأساس لإجراء المزيد من الأبحاث وتطوير تطبيقات عملية من شأنها المساعدة في تعزيز بيئة بناء أكثر استدامة.
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Introduction:

The concept of "sustainability," first introduced in the 1989 Brundland Report by the United Nations World Commission on Environment and Development, has been the subject of several studies and projects (Yılmaz and Bakış, 2015). The international community's advocacy of energy and environmental policies that foster economic growth without compromising the environment forces states, establishments, institutions,

corporate society non-governmental groups, and other parties to take such actions. The building, maintenance, and dismantling of these structures raise a number of environmental concerns. In addition to contributing to climate change, energy-intensive buildings have an impact on the city's water and air quality (Vyas et al., 2014). According to data from 2010, buildings consume 45% of the world's energy and 50% of its water. Buildings are the cause of 50% of GHGs (greenhouse gas emissions), 40% of solidified waste, 40% of water pollutants and 23% of air pollutants (Dixon, 2010). These building-related environmental problems can be greatly minimised by altering the uses. In addition to its most evident or measurable effects on the environment, industry has substantial detrimental socioeconomic implications.

According to the CIB's (2002) research, the construction industry's organisational structure, performance, and structure have the potential to enhance economic sustainability. Due to globalisation and the increasing usage of imported resources, national organisations are no longer able to compete with international organisations, which reduces GNP and makes it more difficult for them to make financial decisions domestically. Due to its high waste output and excessive consumption of resources, the construction industry is not only economically inefficient but also unable to support environmental sustainability (Yılmaz and Bakış, 2015). On the other hand, due to its high labour costs, the construction sector has the potential to greatly raise the standard of living for those with low incomes by generating employment opportunities. It can contribute to greater social sustainability by keeping individuals out of poverty.

Automation and computerization systems that assist in managing, measuring, and keeping an eye on the primary technical parameters of building processes and their deviations are currently necessary for the execution of technological processes in the construction industry (Komarov, 2019). The development of "smart sensors" that display the values of the parameters on liquid crystal metrics, transform the parameters being measured into unified signals for transmission through channels of communication and help determine the values of indirect variables based on direct measurements using preprogrammed formulas was made possible by a significant increase in the capabilities and a decrease in the cost of automated systems and microprocessor devices. To facilitate the construction process, new measurement instruments have been created, including Coriolis flow meters, radar level meters, ultrasonic meters and electromagnetic (Skorobogatova et al. 2021). In addition to automating some measurement equipment and tools, construction organizations also utilize automated process control systems (APCS) to monitor and oversee their operations. Innovations in the construction sector include the use of advanced technology and materials, as well as the implementation of automated information systems for construction management throughout a project's life cycle (Kuklina et al. 2021). Following the completion of construction projects, advertising and investment management techniques are employed.

Literature Review

The use of sustainable practices can have a significant positive impact on construction projects. Sustainability is becoming a more important consideration in project management strategies. It has been demonstrated by Carvalho et al. (2014) and De Azevedo et al. (2020) that civil construction materials are important for carrying out sustainable projects. The lack of natural resources compels the building industry to adopt new ideas and technological "green" solutions, which in turn forces the sector to use SD (Azevedo et al., 2019). Sustainable PM ideas have been more well-liked even if sustainable materials appear to be a part of contemporary operations. The Paper will critically review several research articles regarding sustainability, innovative materials, management and construction techniques used in the construction industry.

2.2 Theocratical Underpinning

2.2.1 Resilience Theory

Resilience theory examines how people react to, bounce back from, and adjust to difficulties, stressors, or adversities as individuals, groups, communities, or systems. Numerous academic fields, including psychology, sociology, ecology, organizational studies, and disaster management, can benefit from its use (Van Breda, 2001). The ability of systems to endure and bounce back from shocks, such as natural disasters and climate change, is highlighted by the resilience theory. Positive actors that improve resilience and lessen the effects of stressors are included in the theory (e.g., supportive relationships, self-efficacy, access to resources). Resilience entails preserving functionality within predetermined bounds. Systems may change to a fundamentally different state (such as ecological collapse or psychological breakdown) if these thresholds are exceeded. Resilience theory is applied in sustainable construction by creating structures that are resilient to natural disasters, energy-efficient, and flexible enough to adjust to shifting environmental conditions.

2.3 Sustainable Materials Used in the Construction Industry

It is expected that cement-based composites may eventually be replaced by geopolymers (Nawaz et al. 2020). These inorganic polymers are categorized as synthetic inorganic aluminosilicate-based polymers and have a ceramic-like appearance. They consist of a reactive powder, such as fly ash or metakaolin, which are sources of silicon and aluminium, and an activating alkaline solution, such as sodium or potassium hydroxide (Provis and van Deventer, 2009). One silicon or aluminium atom is covalently bonded to four oxygen atoms to form chains or networks of inorganic molecules. A single oxygen atom then connects these tetrahedrons to create a three-dimensional network. They have a similar chemical makeup to zeolitic minerals found in nature (Nikolova et al., 2017). Many attempts have been made to create schematic representations of the complex three-

dimensional geopolymer structure proposed by Davidovits (2020). By employing a range of methods, such as mercury porosimetry, thermal analysis, MAS NMR spectroscopy based on silicon, aluminium and sodium and BET isothermal curves. Barbosa et al (2000), were able to alter the framework and further explore the microstructure of the alkali-activated products (Barbosa et al. 2000). The structure and mineralogical characteristics of geopolymers are strikingly comparable to those of ceramic substances. They can be used as fillers for gaps and fractures in tiles and repair mortars as an alternative to traditional materials in cultural heritage because of their chemical, physical, and mechanical properties, which make them extremely resilient over time.

2.4 Innovative Construction Techniques

The construction business is adopting technology more slowly than industries including finance, entertainment, healthcare, and education (Thompson et al. 2017). To keep ahead of the competition and preserve efficiency, many businesses in these industries are always searching for fresh and creative ways to use technology. However, one reason for the erratic or intermittent drop in productivity in the construction sector is a lack of investment in technology (Gledson and Greenwood, 2017). Technological advancement requires modern computers, software, servers, and networks, but digitization in the construction sector extends beyond these acquisitions. Incorporating technological advances like artificial intelligence (AI), machine learning, the internet of things (IoT) and big data into routine business processes (Liu et al. 2019). It is concerning since construction workers generally do not embrace novel concepts that necessitate extensive research. According to Sacks et al. (2013), these professionals favour practical, hands-on work over intricate, time-consuming machinery. Companies can still use training and disciplinary actions to ensure that these adoptions are followed. The construction industry will be able to provide more intelligent, economical, and efficient services with even less expensive labour due to digitization, claims UKGOV (2013).

2.5 Sustainable Construction Management Practices

In the United States, buildings are responsible for 39% of primary energy use, 40% of substance consumption, and 38% of CO₂ emissions (Ferdosi et al. 2023). According to Ozcan-Deniz and Zhu (2017), this is because the building industry contributes significantly to the globalization of contamination of the environment. Therefore, the building industry needs to promote innovative and eco-friendly construction methods. International investments in sustainable development are necessary to lessen the built environment's capacity to contribute to global warming. Sustainability, according to some experts, is either increasing building efficiency or designing structures with the least negative environmental impact (Pignataro et al. 2014). Several traits, including technical advancement, social justice and acceptance, economic activity and productivity, and environmental non-destructiveness, characterize modern sustainable development (Shen

et al., 2011). The majority of building types may incorporate a considerable amount of sustainable design at little to no extra expense, claim Dwaikat and Ali (2016). Since they offer frameworks for data integration and reduce debris, emissions of greenhouse gases, and energy usage, digital technologies are essential in sustainability sectors.

Therefore, new technologies that are coming through digital aids help to achieve sustainable sectors (Gharouni et al., 2021). Sustainable building design has included modern technology like BIM in recent years (Ahmadian et al. 2017). Energy and the environment, resources and materials, the interior quality of the environment, feasible sites, innovation, and the construction performance analysis technique are some of the advantageous components of BIM, which offers crucial data and information for projects (Mirpanahi and Noorzai 2021). However, as a technology/approach, BIM facilitates information integration throughout the design phase, increases collaboration, and prolongs the lifespan of a building (Volk et al., 2014). Consequently, studies on the design of sustainable buildings have grown more systematic (Liu et al., 2015). Early in the design and decision-making process, planners and designers can influence the efficiency of energy and the building's life cycle cost by integrating BIM and LCA (Abbasi and Noorzai 2021).

Research Methodology:

Research Approach

This study adopts a deductive research approach, which involves testing predefined hypotheses derived from existing theories and literature. The deductive approach refers to a certain theory testing procedure that commences especially with one established existing theory and generalization, and looks for identifying if that theory implements to particular instances (Spens and Kovács, 2006). The deductive approach is ideal for this research because it allows for the establishment of causal relationships between variables, such as the impact of sustainable materials and innovative techniques on environmental performance. By starting with general premises that narrow down to specific observations, it ensures a structured pathway into addressing the research questions. As such, the study seems to be particularly suited for a study that aims to research the topic of sustainability in construction; it allows for hypoPaper testing to be done through quantitative methods like regression and ANOVA. The deductive approach enhances the research's scientific rigor by providing a clear framework for data analysis and hypothesis testing, ultimately leading to actionable conclusions aligned with the study's objectives.

3.4. Research Strategy

The survey strategy is employed in collecting primary data so that it would be efficient and standardized to collect responses from the participants. Sometimes survey very

simply estimates staff understanding (de Waal, 2014). Microsoft Forms was chosen for the purpose of data collection due to its user-friendly interface, easy distribution, and automatic collation of data, which was easier to carry out on both sides, the researcher's side and the respondents'. To attain an appropriate questionnaire, the researcher carefully designed the survey instrument. The questionnaire contained closed-ended questions and a Likert scale to measure respondents' perceptions and experiences quantitatively. Therefore, the closed-ended question insured consistent responses, and in order to present detailed analysis of attitudes and behaviors related to sustainability practices, the Likert scale is used. The target population to be surveyed is construction professionals or stakeholders who have knowledge and experience in sustainable construction.

3.5 Sampling method

A convenience sampling method was used. This allowed the researcher to collect responses from a readily accessible pool of participants. Convenience sampling refers to a certain non-probabilistic sampling technique (Suen, Huang and Lee, 2014). Convenience sampling has limitations in generalizability, but it was appropriate for this study because of time and resource constraints. The final sample size of 39 respondents provided a basis for statistical analysis, offering insights into the role of sustainable materials, innovative techniques, and management practices in enhancing environmental performance. This approach ensured relevance, reliability, and alignment of the data collected with the research objectives.

3.7 Data Collection and Processing

The data collection process was done using Microsoft Forms to distribute a structured survey to participants. Microsoft Forms was chosen for its accessibility, ease of use, and ability to automate data collation, ensuring that responses were captured accurately and efficiently. Though, the overall availability of this Microsoft Forms can depend on a person's Office 365-based version (Rhodes and Rhodes, 2019). The survey consisted of carefully designed questions aligned with the research objectives, including closed-ended and Likert-scale questions to quantify respondents' perceptions and behaviors regarding sustainability in construction. Ethical considerations were maintained during data collection. No personally identifiable information was collected to ensure anonymity and confidentiality, and respondents were informed that participation was voluntary. A consent statement was included at the start of the survey to reinforce ethical compliance.

After data collection, raw survey data was cleaned to address inconsistencies, missing responses, and outliers to ensure the integrity of the dataset. The cleaned data was prepared for analysis using SPSS, which is a statistical software tool. The processing of data in SPSS includes coding responses, conducting descriptive statistics to summarize the data, and running regression analysis and ANOVA to test hypotheses. In this case, the proper analysis of data was performed to develop meaningful insights regarding the role

of sustainable materials, techniques, and management practices in improving environmental performance.

3.8 Data Analysis Methods

The data analysis of the study will use several statistical tools to draw meaningful insights into the responses of the questionnaire. Descriptive statistics, as a preliminary tool in analyzing the data, enabled summarizing and understanding the nature of the data. Descriptive statistics mainly represents one crucial first and foremost step while accomplishing the research (Kaur, Stoltzfus and Yellapu, 2018). Means and standard deviations were measures that provided an overview of how the responses were distributed and consistent. The above metrics enabled clear depictions of trends and patterns in the utilization of sustainable materials, techniques, and management practices during construction projects. Regression analysis was carried out to derive relationships between the independent variables—sustainable materials, innovative construction techniques, and management practices—and the dependent variable, environmental performance.

This method was applied due to its capability for quantifying the strength as well as direction of relationships and, therefore, able to directly answer the questions set out in the present study. For example, regression analysis helps in measuring the amount of variance in the environmental performance that can be explained by the adoption of certain sustainable practices. Testing hypotheses about causal linkages requires its application, which eventually leads to actionable insights. In general, ANOVA was used to test hypotheses related to mean comparisons in groups. ANOVA is mainly used for testing key differences mainly between “three or more sample means” (Tello and Crewson, 2003). For example, ANOVA was used to compare respondents' responses among different professional groups or organizational functions.

3.9 Reliability and Validity

Reliability and validity of the data were ensured throughout the research process. In this field of “questionnaire development” and “psychometrics” concepts of validity and reliability are quite crucial to development of “measurement instruments” which may be very useful for research (Bannigan and Watson, 2009). Reliability was maintained through a well-structured questionnaire, as the consistency in responses during the survey was maintained. Pilot testing was conducted before the main survey to ensure that questions were clear, concise, and elicited consistent responses. This ensured that ambiguity was reduced, and the data collected became more reliable.

The survey questions were aligned directly with the research objectives and theoretical constructs identified in the literature review to ensure validity.

Findings and Discussion

4.2.1 Demographic analysis

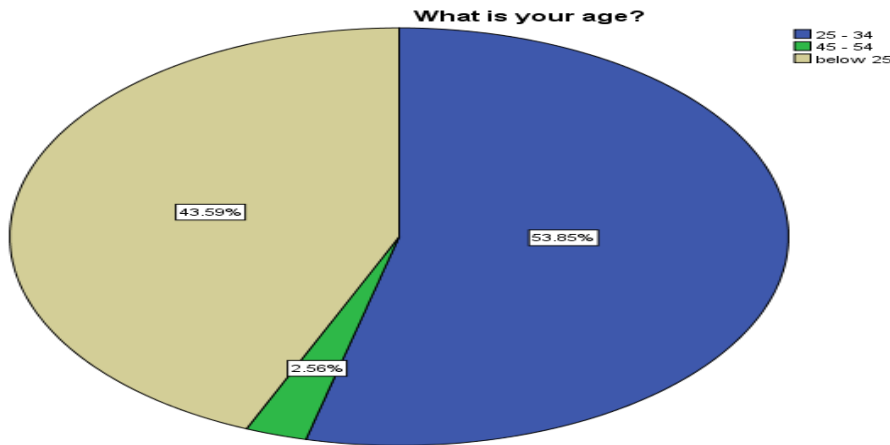


Figure 1: Age Distribution
(Source: IBM SPSS)

The majority (53.85%) of respondents are aged 25-34, which reflects a relatively young population in the construction industry. The second most significant age group, 45-54 years, accounts for 43.59%, which means it is an aging workforce at or close to the senior level or retirement. The youngest group (2.56%) is under 25, indicating fewer new entrants to the industry. This profile would likely indicate experience transfer and succession planning issues because so many in this workforce are approaching retirement.

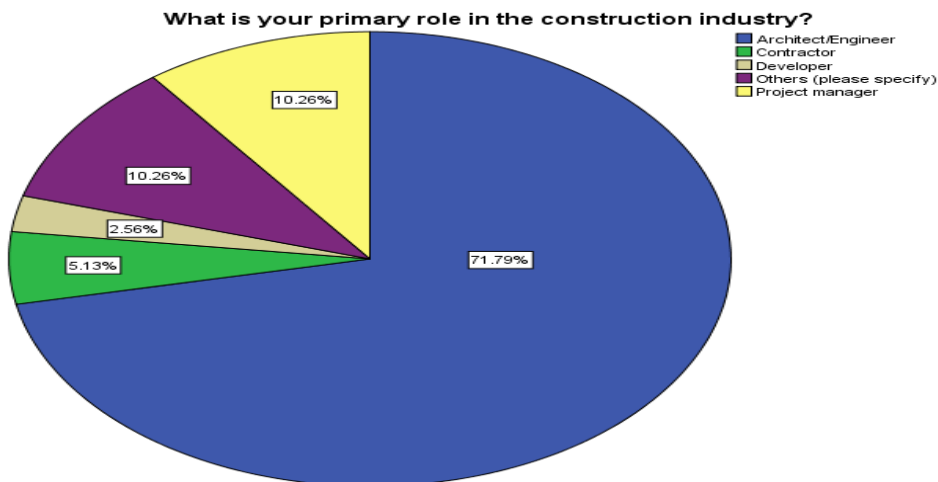


Figure 2: Role in construction industry
(Source: IBM SPSS)

A high proportion of the respondents are Architects or Engineers (71.79%), which indicates a high representation of these professionals in the industry. The remaining roles,

such as Contractors, Developers, and Project Managers, are less represented, with 10.26%, 5.13%, and 2.56% respectively, indicating a skew of the sample towards design and technical expertise. This could either be a reflection of the focus areas of the study or an overall trend in the industry favoring technical roles.

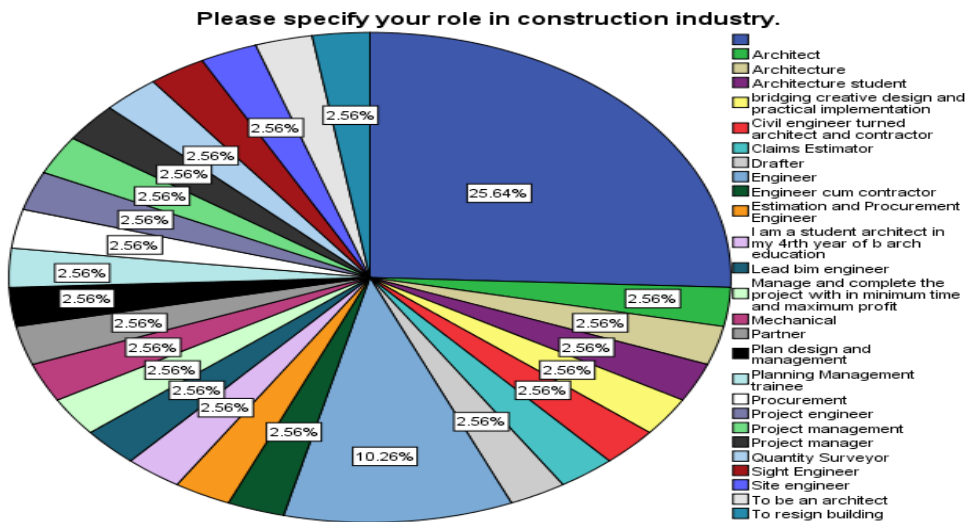


Figure 3: Role in the construction industry
(Source: IBM SPSS)

This detailed chart reveals all kinds of roles in the construction industry, with a more focus on engineering and architecture. The most prominent is the Engineers (25.64%), and other specific job positions each make up lesser percentages, showing that much diversified expertise is involved in a construction project. This calls for an interdisciplinary nature of this industry, which requires collaboration from these diverse specialized fields.

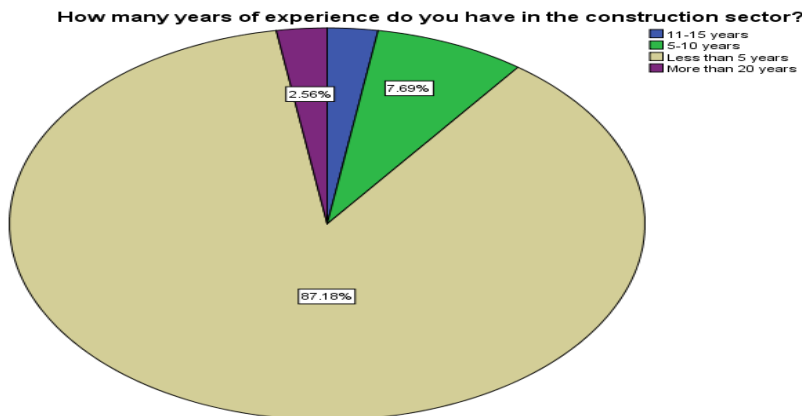


Figure 4: Year of experience in construction industry
(Source: IBM SPSS)

Dominantly, participants (87.18%) have over 20 years of experience, suggesting an experienced workforce well-versed in traditional construction methods. Those with 11-15 years and 5-10 years are significantly fewer (7.69%, 2.56% respectively), pointing to a potential gap in mid-career professionals which might affect the industry's adaptability and innovation potential.

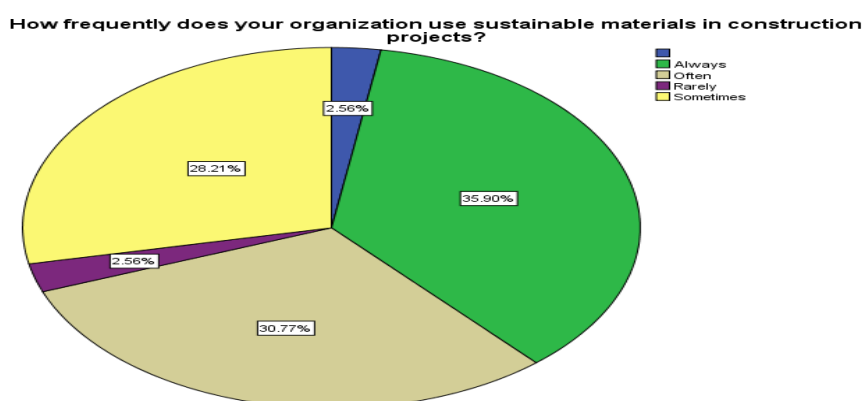


Figure 5: Frequency of usage of sustainable materials in construction industry

The statistics show that the use of sustainable materials is diverse, with most organizations using them frequently (35.90%) or occasionally (30.77%). A significant number of organizations rarely use sustainable materials (28.21%), and only a few always use them (2.56%). This diversity implies that although sustainable materials are becoming popular, there are still significant barriers to their widespread adoption in projects.

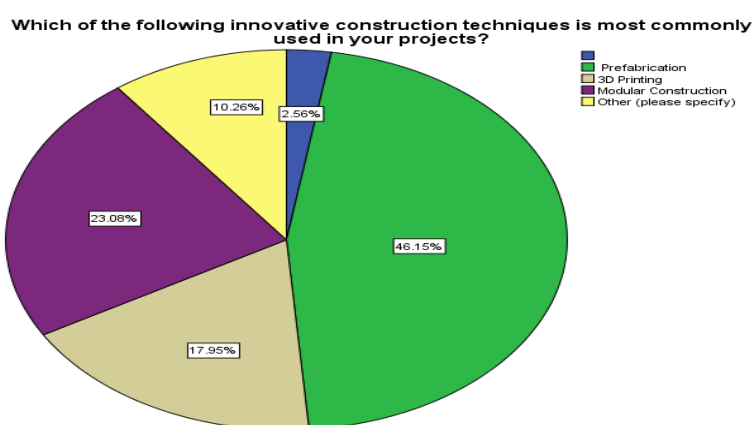


Figure 6: Innovative construction techniques used in construction industry

Prefabrication stands as the top innovative technique (46.15%) indicating a paradigm shift toward more efficient, controlled, and less wasteful construction processes. Other recent techniques, 3D Printing and Modular Construction, are lesser in count but might indicate either an emerging trend or areas of niche applications in the business.

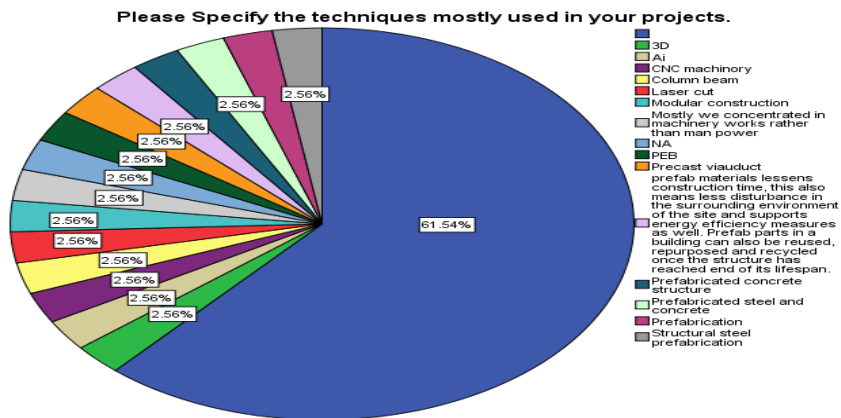


Figure 7: Specific construction techniques

The high percentage of prefabrication (61.54%) shows that it is well accepted as one of the most important modern construction methods, which saves time and resources. The existence of many other techniques, each represented by a small percentage, indicates a wide exploration of technologies and methods in the pursuit of efficiency and sustainability in construction projects.

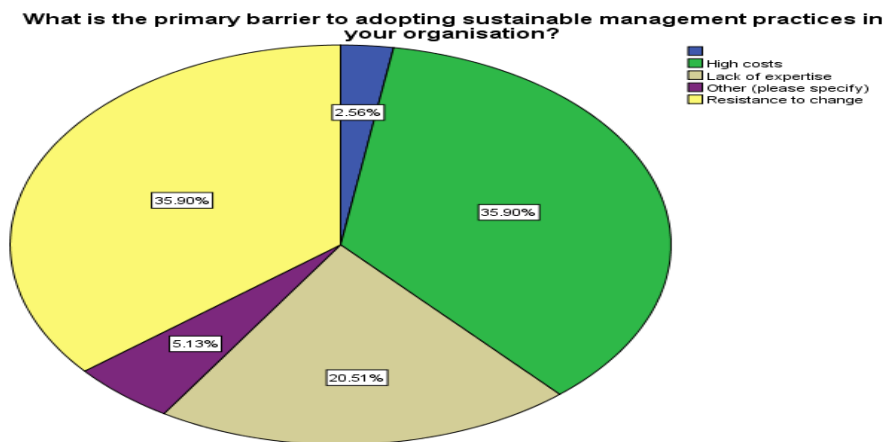


Figure 8: Primary barriers in adopting sustainable management practices in construction industry, High cost and resistance to change with equal prominence at 35.90% each point to common challenges in adjustments in organizations and operations. Economic and cultural issues that need to be addressed to enhance sustainability in construction.



Figure 9: Sustainable practices in construction industry

Majority fails to cite practices aside from the ones stated (84.62%). This might point to either a lack of awareness about other available sustainable practices or to the implementation of other types of sustainability options. It is likely that other types of sustainability efforts are where the industry may want to see more improvement in practice and also focus.

4.2.2 Inferential statistics

4.2.2.1. Descriptive analysis

	Descriptive Statistics					
	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Deviation Statistic	Skewness Statistic
How significant is the role of sustainability in your organization's decision-making ...	37	1	3	1.68	.818	.682
Using sustainable materials significantly reduces the environmental impact of construction projects ...	39	1	2	1.46	.505	.161
Sustainable materials are cost-effective in the long run. IV2	39	1	4	2.08	.639	.132
Innovative construction techniques play a crucial role in minimizing construction waste. IV3	39	1	3	1.59	.595	.426
Adopting advanced techniques improves energy efficiency in construction projects. DV2	39	1	4	1.69	.694	.998
Sustainable management practices enhance the overall performance of construction projects. DV3	39	1	4	1.92	.664	.652
Management practices that prioritize sustainability are feasible within existing project budgets. IV4	39	1	4	2.18	.885	.351
Training and development programs are necessary to promote sustainability adoption in the construction sector. DV4	39	1	2	1.44	.502	.269
Valid N (listwise)	37					

Figure 10: Descriptive Analysis

Figure 10 delivers an all-inclusive statistical outline of variables related to sustainable practices in the construction sector. It analyses the role played by sustainability in decision-making procedures, the effectiveness and impact of adopting sustainable materials, and the effectiveness of innovative construction techniques. The variable of importance of sustainability in decision-making process scored a mean of 1.68 and, in general, there was a low influence exerted by sustainability in organizational decisions. There was low variation in the replies as indicated by the standard deviation of 0.818, implying a consistent underemphasis by respondents.

Conversely, the utilization of sustainable materials and their contribution to environmental protection are better known, with means of 1.40 and 2.08, respectively. This suggests a recognition of the need for them but also suggests a potential gap in exploiting these materials to the full in terms of environmental impact. Similarly, the score for long-run cost-effectiveness of sustainable materials also presents a middle level of agreement at a mean of 2.08, which suggests a cautious optimism about long-run financial payback.

A significant high mean of 3.59 for innovative construction techniques is a critical role in the minimization of waste suggests a good level of consensus and, hence, the forward-thinking industry professionals. The need for training in sustainable development was scored less, at 1.44, and suggests that such education needs may be much less identified but could become essential in boosting the implementation and uptake of sustainable practice throughout the industry.

4.2.2.2. Factor analysis

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.689
Bartlett's Test of Sphericity	Approx. Chi-Square	110.538
	df	28
	Sig.	.000

Figure 11: Factor Analysis

Figure 11 describes the factor analysis with the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test, which are necessary for determining whether the data are appropriate for this type of statistical analysis. The KMO measure at 0.689 indicates that the sample adequacy is moderate, which means that the dataset has enough common variance to provide a reliable factor analysis. Bartlett's test tests the appropriateness of the correlation matrix with a very high p-value of 0.000, which permits investigating the underlying factors. This analysis searches for latent variables that affect sustainability practices, which may provide much deeper insights into how various facets of sustainability are related within the construction industry. Those relationships can help industry leaders and policymakers develop more strategic approaches to improve sustainability within construction projects.

4.2.2.3. Reliability test

Reliability Statistics					
Cronbach's Alpha		N of Items			
.828		8			

ANOVA with Cochran's Test					
		Sum of Squares	df	Mean Square	Sig.
Between People		65.986	36	1.833	
Within People	Between Items	19.243	7	2.749	50.599
	Residual	79.257	252	.315	.000
	Total	98.500	259	.380	
Total		164.486	295	.558	

Grand Mean = 1.74

Figure 12: Reliability test

This figure 12 shows the test carried out using Cronbach's alpha paired with Cochran's Q test as part of carrying out an ANOVA to test the consistency or homogeneity of a subset of eight items in an instrument designed to survey practitioners on sustainability practices in construction. The Cronbach's Alpha value of 0.828 suggests that the internal consistency among the items was highly high, which showed they measure the same thing very reliably. A high value for alpha is desirable since it would indicate that there are well-correlated items that fit well to a cohesive scale in measuring the perceptions as of the respondents.

ANOVA with Cochran's Q Test will be used to detect the differences among responses across various subjects. A very significant Cochran's Q of 50.599 at .000 p-value points to a consistent difference between the items in how subjects responded. This may also translate to saying that despite being internally consistent, individual differences in the response patterns occur in the subject's responses, and this difference is statistically significant. With a Grand Mean of 1.74, generally across the items, there was an overall low mean level of responding, which generally meant agreement with the survey statements cautiously or in moderation. This combined analysis provides strong statistical backing that the survey is both reliable and discerning in capturing varied responses across participants.

4.2.2.4. Hypotheses Testing

H1: *The use of sustainable materials significantly influences the role of sustainability in an organization's decision-making process.*

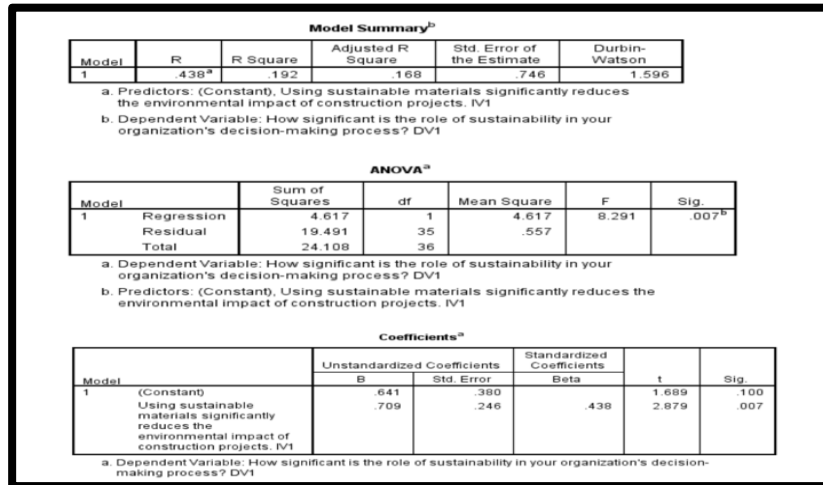


Figure 13: Hypothesis testing 1

Figure 13 Analysis Examines influence of using sustainable materials to the role of sustainability in a firm's decision-making The regression model gives an R-squared value of 0.192, meaning that there is the explanation of the significance or importance of sustainability in terms of decision-making up to 19.2 percent due to using sustainable material. It therefore presents the moderate percentage but of notable and not too minor importance. The ANOVA results support this with a significant F-value of 8.291 at a significance level of 0.007, confirming the model's ability to distinguish effects beyond random chance.

The regression coefficient for using sustainable materials is positive ($\beta = 0.709$), with a significant p-value of 0.007, indicating that the higher the use of sustainable materials, the more focus there is on sustainability in the decision-making process. This positive association is important because it supports the idea that practical sustainability measures, such as the adoption of sustainable materials, are not just operational choices but part of strategic decision-making processes in organizations.

H2: *Sustainable materials' long-run cost effectiveness positively impacts adopting advanced techniques to improve energy efficiency in construction projects.*

Model Summary ^a					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.358 ^a	.128	.105	.657	2.073

a. Predictors: (Constant), Sustainable materials are cost-effective in the long run IV2
b. Dependent Variable: Adopting advanced techniques improves energy efficiency in construction projects. DV2

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.345	1	2.345	5.436	.025 ^a
	Residual	15.963	37	.431		
	Total	18.308	38			

a. Dependent Variable: Adopting advanced techniques improves energy efficiency in construction projects. DV2
b. Predictors: (Constant), Sustainable materials are cost-effective in the long run IV2

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.078	.284		3.796	.001
	Sustainable materials are cost-effective in the long run IV2	.296	.127	.358	2.331	.025

a. Dependent Variable: Adopting advanced techniques improves energy efficiency in construction projects. DV2

Figure 14: Hypothesis testing 2

Figure 14 measures the impact of cost-effectiveness in the long term of sustainable materials towards using advanced techniques to maximize the energy efficiency of construction operations. The model has only an R-squared of 0.128 showing that 12.8% of the variability when using energy efficiency techniques adopted could be due to opinions concerning the cost-effectiveness of sustainable materials. While this suggests a smaller effect size, the positive and significant regression coefficient ($\beta = 1.078$, $p = 0.025$) confirms that perceptions of cost savings and financial benefits from sustainable materials positively influence the adoption of energy-efficient technologies.

The ANOVA supports the model with a highly significant F-value of 5.436 at a significance level of 0.025. This shows that the cost-effectiveness of sustainable materials is a factor in decisions on energy efficiency but not the only factor determining it. The positive beta coefficient indicates that as perceived long-term savings and benefits of sustainable materials increase, so does the likelihood of using advanced energy-saving techniques in construction.

H3: *Innovative construction techniques play a critical role in enhancing the overall performance of construction projects.*

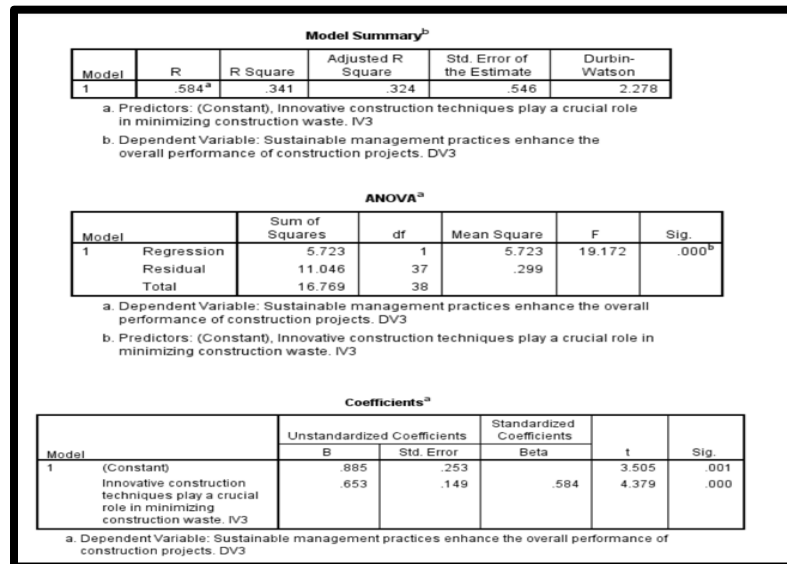


Figure 15: Hypothesis testing 3

Figure 15 examines the extent to which innovative construction techniques affect the overall performance of construction projects. The model of regression indicates a relatively high R-squared value of 0.341. This means that 34.1% of the enhancement in project performance can be explained by the application of innovative construction techniques. This would mean that these techniques play an important role in enhancing project outcomes. The ANOVA result of the model further established a good fit, highly significance F-value of 19.172 with a p-value of 0.000, which indicates an interesting statistical relationship.

The regression coefficients are particularly telling, reporting a significant positive beta for the innovative construction techniques, $\beta = 0.584$, $p = 0.000$. What this result suggests is that what matters is not so much this being a technological advance but that it forms the critical link to tangible and improved management of construction project activities and outcomes. Such innovative techniques seem to relate closely to waste reduction, optimal resource use, better efficiency, and quality in construction operations.

H4: *Management practices that prioritize sustainability within existing project budgets positively influence the need for training and development programs to promote sustainability in the construction sector.*

Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.234 ^a	.055	.029	.495	1.897

a. Predictors: (Constant), Management practices that prioritize sustainability are feasible within existing project budgets. IV4
b. Dependent Variable: Training and development programs are necessary to promote sustainability adoption in the construction sector. DV4

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.524	1	.524	2.140	.015 ^b
	Residual	9.066	37	.245		
	Total	9.590	38			

a. Dependent Variable: Training and development programs are necessary to promote sustainability adoption in the construction sector. DV4
b. Predictors: (Constant), Management practices that prioritize sustainability are feasible within existing project budgets. IV4

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.147	.213		5.380	.000
	Management practices that prioritize sustainability are feasible within existing project budgets. IV4	.133	.091	.234	1.463	.015

a. Dependent Variable: Training and development programs are necessary to promote sustainability adoption in the construction sector. DV4

Figure 16: Hypothesis testing 4

Figure 16 discusses whether management practices that focus on sustainability in project budgets influence the need for training and development programs for the promotion of sustainability in the construction sector. The model indicates an R-squared value of 0.055, which suggests that 5.5% of the variance in the necessity for training and development programs can be explained by how management practices incorporate sustainability. This modest influence suggests that other factors also play significant roles. However, the ANOVA is significant at $p = 0.015$, $F(1, 37) = 2.140$, which affirms the influence of management practices on training needs.

The regression output shows a beta coefficient of 0.234 with a p-value of 0.015, indicating a positive but mild relationship between sustainability-focused management practices and the perceived need for training and development. This implies that when management practices visibly support sustainability, it may create a perceived need to enhance employee skills and knowledge in that area, aligning staff capabilities with organizational goals in sustainability.

Conclusion

This study on the impact of sustainable and innovative practices within the construction industry unveiled crucial insights that resonated well with the rising emphasis on sustainability in business operations across the world. The research looked at how sustainability materials, cost-effectiveness, innovative techniques, and management practices build sustainability on construction projects. All the four hypotheses and tested unique perspectives on the integration and implication of the practices.

First, the utilization of sustainable materials was highly positively correlated with the role of sustainability in organizational decision-making processes. This goes to show that sustainable materials do not only conserve the environment but play a strategic role in the

shaping of corporate sustainability policies. The results showed that organizations that implement sustainable materials into their operations are likely to embrace sustainability more generally in their strategic decisions, thus implying a comprehensive approach to sustainability beyond traditional environmental issues. The hypothesis of cost-effectiveness of sustainable materials shows that long-term financial gains of sustainable materials have a positive impact on the implementation of energy-efficient construction methods. Despite a moderate effect size, this supported that economics played a key role in decisions involving the adoption of environmentally responsible practices, in line with industry's thrust to simultaneously address both economic and environmental bottom lines.

In addition, leading-edge construction techniques had a remarkable ability to improve the all-around performance of construction work. This finding underscores the importance of technological advancement in the construction industry, advocating for the shift towards more sophisticated and efficient methods that can lead to better project outcomes and a reduced environmental impact. Finally, it was found that management practices, which emphasize sustainability, significantly influence the need for training and development programs aimed at promoting sustainability. This suggests that management level commitment to sustainability is more critical in propelling an organizational culture embracing continuous learning and development in the execution of sustainable practices.

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