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Structural Equation Modelling of Barriers, Adoption Behaviour and Sustainability Outcomes in the Built Environment in Northern Nigeria

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ABSTRACT

Sustainability outcomes in the built environment depend on how adoption of sustainable practices interacts with structural constraints, yet the combined effect of these factors remains insufficiently examined. This study examined the relationships between perceived barriers, adoption of sustainable practices and impact within the built environment sector. A quantitative survey design was adopted, drawing on responses from 398 professionals in architecture, engineering, construction and related fields. Data were analysed using descriptive statistics, reliability testing, correlation analysis and Structural Equation Modelling. The measurement scales demonstrated acceptable reliability, with Cronbach's alpha values ranging from 0.761 to 0.859. Descriptive results indicate high perceived barriers, moderate adoption levels and relatively strong perceived impact. Correlation analysis shows a strong negative relationship between barriers and adoption, while relationships involving impact are weak. Structural modelling results show that barriers significantly reduce adoption ($\beta = -0.637$, $p < 0.001$). Adoption has no significant effect on impact ($\beta = 0.058$, $p = 0.431$). Barriers have a significant direct effect on impact ($\beta = 0.216$, $p = 0.001$). The indirect effect is not significant ($p = 0.425$), indicating no mediation effect. The model explains 40.5 percent of variation in adoption and 3.4 percent in impact, indicating limited explanatory power for outcome performance. The findings contribute empirical evidence that structural constraints dominate both behavioural and outcome pathways, while adoption alone does not translate into improved impact. This suggests that sustainability interventions in the built environment are more effective when they prioritise removal of systemic constraints rather than focusing solely on increasing adoption levels.

INTRODUCTION

The built environment remains one of the largest contributors to global environmental pressure through intensive energy use, material consumption and carbon emissions. The construction sector therefore occupies a central position in global sustainability transitions, particularly through the adoption of environmentally sustainable architectural practices such as passive design systems, renewable energy integration, energy-efficient technologies and low-impact building materials (United Nations Environment Programme [UNEP], 2022).

Despite growing international attention, the adoption of sustainable architectural practices remains uneven across developing economies. In Sub-Saharan Africa, rapid urbanization and increasing infrastructure demand continue to reinforce dependence on conventional construction approaches characterized by high energy consumption and weak environmental performance (Kameni Nematchoua & Marie, 2025). In Nigeria, the construction sector has expanded considerably due to urbanization and economic growth. However, sustainability adoption remains relatively slow, largely because construction activities continue to prioritize short-term economic considerations over long-term environmental objectives (Unegbu *et al.,* 2025). In Northern Nigeria, these challenges are intensified by extreme climatic conditions, limited green infrastructure, weak institutional capacity and increasing urban expansion pressures. Although climate-responsive architecture offers considerable potential for improving environmental performance in the region, its integration into mainstream architectural practice remains limited (Noah & Çağnan, 2021).

Existing studies have identified several factors constraining the adoption of sustainability practices within the built environment, including high implementation costs, limited technical expertise, inadequate policy support, weak regulatory enforcement and low stakeholder awareness (Darko *et al.,* 2017). Recent evidence further suggests that sustainability adoption is shaped by interconnected institutional, economic and behavioural conditions rather than isolated determinants (Agyekum-Mensah, 2021). However, much of the empirical literature relies on conventional regression techniques that examine these factors independently, thereby limiting understanding of the structural relationships linking barriers, adoption behaviour and sustainability performance.

Structural Equation Modeling (SEM) has gained increasing application in sustainability and construction research because of its ability to analyse complex relationships among multiple latent constructs simultaneously. The approach permits estimation of both direct and indirect effects while accounting for measurement error, making it particularly suitable for modelling sustainability systems

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involving institutional constraints, behavioural adoption patterns and environmental outcomes. Previous studies have shown the usefulness of SEM in explaining interactions among major drivers of sustainable construction practices (Hwang *et al.,* 2019). Nevertheless, important empirical and methodological gaps remain. Existing studies rarely integrate barriers, adoption behaviour and sustainability outcomes within a unified structural framework, particularly in developing regions where sustainability transitions remain institutionally constrained. Empirical evidence from Northern Nigeria also remains limited despite increasing environmental pressures and rapid urban growth (Mobolade & Pourvahidi, 2020). Furthermore, the application of SEM to environmentally sustainable architectural practices within the Nigerian construction sector remains relatively underdeveloped.

This study addresses these gaps by applying SEM to examine the interrelationships among barriers, adoption and sustainability outcomes of environmentally sustainable architectural practices in Northern Nigeria. The study assesses the level of sustainability adoption, identifies major constraints affecting implementation and evaluates the extent to which adoption pathways influence sustainability outcomes. The integrated modelling framework allows simultaneous estimation of these relationships while extending the application of SEM within sustainable construction research. The study also provides empirical evidence from Northern Nigeria and offers policy-relevant findings capable of supporting sustainable building development and environmental planning strategies.

LITERATURE REVIEW

Sustainable architectural practices have received growing attention in construction and environmental research due to the rising contribution of the built environment to energy use, carbon emissions and resource depletion. Global reports indicate that although awareness of green building principles continues to increase, implementation remains limited, particularly in developing economies where institutional capacity and structural conditions strongly influence construction decisions (World Green Building Council, 2023; UNEP, 2022).

A wide range of studies has examined factors influencing the adoption of sustainable construction practices. Darko *et al.* (2017) identified financial constraints, limited technical competence and weak institutional support as major barriers to green building adoption. Chan *et al.* (2017) reported that regulatory pressure and client awareness influence adoption decisions, although cost considerations remain dominant. Similarly Arcega *et al.* (2025) found that in CAMANAVA, knowledge significantly shapes public attitudes toward environmental issues, while socio-demographic factors have little influence. These findings indicate that adoption is shaped by both economic and institutional conditions rather than awareness alone.

Evidence from developing regions shows similar patterns. Studies in Sub Saharan Africa report that implementation remains constrained by institutional weaknesses, limited access to green technologies and capacity limitations (Olawumi & Chan, 2020). Construction sustainability research in similar contexts further emphasizes that adoption is shaped by structural and institutional conditions, highlighting the role of system level constraints in sustainability outcomes (Windapo, 2014).

Within Sub Saharan Africa, additional constraints such as fragmented policy structures, weak technological diffusion and low market demand continue to limit adoption even under rapid urban growth conditions (Opoku & Ahmed, 2015). Further studies report that weak fiscal incentives, limited awareness and insufficient institutional support continue to slow green building diffusion across the region (Addy *et al.,* 2022). Broader African evidence also shows that weak professional capacity and limited access to enabling technologies reinforce these constraints and reduce adoption rates (Mushi *et al.,* 2022). These factors interact rather than operate independently, indicating that adoption outcomes are shaped through interconnected systems of influence.

In Nigeria, empirical evidence shows more context specific barriers to sustainable construction adoption. Augustine and Akanni (2024) found that high construction costs, weak regulatory enforcement and limited awareness of long term benefits reduce adoption of green building practices. Mogaji *et al.* (2024) reported that weak policy implementation, limited access to sustainable materials and inadequate financial incentives continue to hinder sustainability uptake. Ofori (2018) identified technical limitations, cultural resistance and weak institutional coordination as additional constraints affecting integration of sustainable design practices. Industry based evidence further shows that limited institutional support and inadequate knowledge of green technologies remain persistent barriers in the Nigerian built environment sector (Agboola *et al.,* 2024). Onyemenam (2025) observed that adaptive green infrastructure projects in urban Nigeria, while improving environmental quality and climate resilience, may also contribute to rising housing costs and displacement pressures among low-income residents due to weak housing protection policies, insecure land tenure, and limited community participation in urban planning processes.

Research on sustainable construction adoption increasingly emphasizes interactions among determinants rather than isolated effects. Empirical studies indicate that economic, institutional and behavioural factors are interdependent in shaping adoption outcomes (Agyekum-Mensah *et al.,* 2021). Structural Equation Modeling has therefore become widely used in sustainability research due to its ability to estimate relationships among latent constructs simultaneously. Kineber *et al.* (2023) reported that this approach improves analytical performance in sustainability studies by accounting for measurement error and capturing both direct and indirect effects among variables. Other studies in construction management also show that adoption processes are better represented as interconnected systems rather than linear relationships.

Despite these developments, the literature does not yet provide a unified analytical framework that integrates barriers, adoption behaviour and environmental outcomes. Most studies examine these components separately, limiting understanding of how adoption mediates the relationship between constraints and sustainability outcomes. Evidence from Northern Nigeria remains limited despite rapid urban growth, environmental stress and infrastructural challenges that increase the relevance of sustainability research in the region. Sustainable architectural adoption is shaped by interconnected economic, institutional, technical and market factors that operate as a system rather than isolated variables. Existing approaches remain fragmented and do not fully capture these relationships, creating the need for a unified model capable of estimating both direct and indirect effects within the Nigerian built environment.

MATERIALS AND METHODS

Study Design and Data Collection

A quantitative cross-sectional survey design was adopted to examine relationships among barriers, adoption and environmental outcomes of sustainable architectural practices. Data were collected from built environment professionals in Northern Nigeria, including architects, civil engineers, environmental consultants, builders, quantity surveyors and urban planners. A structured questionnaire was distributed using a purposive sampling approach targeting practitioners with direct involvement in building design and construction activities. A total of 398 valid responses were retained after data screening for completeness and consistency.

Instrument Development and Measurement

The questionnaire was developed from established literature on sustainable construction and green building adoption and adapted to the Nigerian built environment context. All items were measured on a five-point Likert

Table 1: Measurement of Constructs and Indicators

Construct	Code	Measurement Indicator
Economic Barriers	B1	Sustainable building materials are too expensive for most projects
	B2	Initial cost of sustainable design discourages clients
	B3	Limited financial incentives for sustainable construction
	B4	Life cycle cost benefits are not well understood
Technical Barriers	B5	Shortage of professionals with sustainability expertise
	B6	Limited access to sustainable construction technology
	B7	Inadequate technical knowledge of green building design
	B8	Limited availability of sustainable design tools and software
Institutional Barriers	B9	Weak government policies supporting sustainable architecture
	B10	Poor enforcement of sustainability standards in building regulations
	B11	Weak institutional support for green building adoption
Market and Social Barriers	B12	Clients prefer conventional building designs
	B13	Low awareness of sustainable architecture benefits
	B14	Low market demand for green buildings
	B15	Resistance to change from traditional practices
Energy Efficiency Practices	A1	Use of energy efficient lighting systems
	A2	Integration of renewable energy systems
	A3	Energy efficient building orientation and design
Passive Design Strategies	A4	Natural ventilation systems in building design
	A5	Daylighting strategies in building design
	A6	Climate responsive design principles
Material Efficiency	A7	Use of locally sourced building materials
	A8	Use of recycled or reusable materials
	A9	Reduction of construction waste in projects
Water Efficiency Systems	A10	Rainwater harvesting systems
	A11	Water efficient fixtures in buildings
	A12	Greywater recycling systems
Economic Impacts	I1	Reduction in operational costs
	I2	Improved long term cost efficiency

	I3	Increase in property value
	I4	Reduction in maintenance costs
Social Impacts	I5	Improved occupant comfort
	I6	Improved indoor air quality
	I7	Improved health outcomes
	I8	Improved quality of urban life
Environmental Impacts	I9	Reduction in carbon emissions
	I10	Reduction in energy consumption
	I11	Conservation of natural resources
	I12	Reduction in urban heat effects
	I13	Reduction in environmental pollution

scale ranging from strongly disagree to strongly agree. The instrument captured three latent constructs comprising barriers to sustainable architectural practices, adoption of sustainable practices and perceived environmental impact outcomes.

The instrument was adapted from prior studies on sustainability in construction and tailored to reflect contextual conditions within the Nigerian built environment. Composite indices were computed using mean aggregation of item responses to ensure comparability across constructs and reduce measurement variability:

$$B_i = \frac{1}{kB}\sum_{j=1}^{k_B} B_{ij} \quad (1)$$

$$A_i = \frac{1}{kA}\sum_{j=1}^{k_A} A_{ij} \quad (2)$$

$$I_i = \frac{1}{kI}\sum_{j=1}^{k_I} I_{ij} \quad (3)$$

where Bi, Ai and Ii represent barrier, adoption and impact indices for respondent i, while k_B=15, k_A=12 and k_I=13 represent retained items used for each construct index computation.

Prior to estimation, data were screened for completeness, distributional properties and potential outliers. No missing values were recorded after data cleaning. Normality was assessed using skewness, kurtosis and the Shapiro Wilk test on model residuals. Multicollinearity was examined using variance inflation factors, while heteroscedasticity was tested using the Breusch Pagan procedure. All analyses were conducted at a 5 percent significance level.

Reliability and Validity Assessment

Internal consistency reliability was assessed using Cronbach's alpha, with the barrier construct recording $\alpha = 0.772$, adoption $\alpha = 0.761$ and impact $\alpha = 0.859$. All values exceeded the 0.70 benchmark commonly used in social science research, confirming acceptable reliability across the measures, with the impact construct showing the strongest internal consistency. Construct validity was examined using confirmatory factor analysis prior to structural estimation and item loadings met acceptable criteria, indicating adequate representation of the constructs and supporting convergent validity.

Analytical Framework and Model Specification

A structural equation modeling approach was employed to examine direct and indirect relationships among constructs. The hypothesised mediation structure assumes that adoption acts as a transmission mechanism between barriers and environmental impact.

The structural model is specified as:

$$Ai=\alpha_0+aBi+\varepsilon_{1i} \quad (4)$$

$$Ii=\beta_0+c'Bi+bAi+\varepsilon_{2i} \quad (5)$$

where a represents the effect of barriers on adoption, b represents the effect of adoption on impact and c' represents the direct effect of barriers on impact.

The indirect and total effects are defined as:

$$\text{Indirect effect}=a\times b \quad (6)$$

$$\text{Total effect}=c'+(a\times b) \quad (7)$$

The model was estimated using maximum likelihood with robust standard errors (MLR) implemented in the lavaan package in R. Model parameters were evaluated using z statistics and corresponding probability values. Model fit was assessed using chi square test, Comparative Fit Index, Tucker Lewis Index, Root Mean Square Error of Approximation and Standardized Root Mean Square Residual.

To assess mediation significance, a bootstrap procedure with 5000 resamples was specified; however, due to convergence instability in some resamples, robust maximum likelihood estimates were used as the primary inference basis.

Ethical Consideration

Participation was voluntary and responses were anonymized to ensure confidentiality. Data were used strictly for academic purposes.

RESULTS AND DISCUSSION

Table 2: Socio-Demographic Characteristics of Respondents (n = 398)

Variable	Category	Frequency	Percent
Profession	Architect	171	43.0
	Urban Planner	17	4.3
	Civil Engineer	42	10.6
	Environmental Consultant	42	10.6
	Builder/Contractor	110	27.6
	Quantity Surveyor	16	4.0
Years of Experience	Below 5 years	8	2.0
	5–10 years	225	56.5
	11–15 years	40	10.1
	Above 15 years	125	31.4
Type of Organization	Private practice	166	41.7
	Government agency	91	22.9
	Construction firm	75	18.8
	Academic/research	66	16.6
Level of Involvement	High	59	14.8
	Moderate	158	39.7
	Low	181	45.5

Table 2 shows that architects and builders/contractors constituted the largest proportion of respondents, indicating strong representation from core built-environment professionals. Most respondents possessed between 5 and 10 years of professional experience and were primarily affiliated with private-sector organizations.

Table 3: Descriptive Statistics of Study Constructs

Construct	Mean	Standard Deviation	Minimum	Maximum
Barrier Index	3.53	0.77	2.33	4.67
Adoption Index	2.75	0.45	1.75	4.08
Impact Index	3.82	0.57	2.15	4.92

Table 3 shows that the perceived impact of the measured practices was rated more strongly than their level of adoption, while barriers remained comparatively high among respondents. Overall, the constructs exhibited moderate response variability, indicating a reasonable level of consistency in respondents' perceptions.

Table 4: Correlation Matrix of Study Variables

Variable	Barrier Index	Adoption Index	Impact Index
Barrier Index	1.000		
Adoption Index	-0.637	1.000	
Impact Index	0.179	-0.079	1.000

The correlation matrix indicates that barriers were negatively associated with adoption, whereas the Impact Index demonstrated only weak relationships with the other study variables. This suggests that perceived impacts may be influenced by factors beyond the barriers and adoption dimensions captured in the study.

Table 5: Structural Equation Model Results

Path	Estimate	Std. Error	z-value	p-value	Std. β
Barrier → Adoption (a)	-0.376	0.023	-16.668	<0.001	-0.637
Barrier → Impact (c')	0.160	0.049	3.242	0.001	0.216
Adoption → Impact (b)	0.073	0.093	0.787	0.431	0.058

The structural model demonstrates that barriers significantly constrained adoption while simultaneously exerting a direct effect on impact. However, adoption did not significantly predict impact, indicating that its

Table 6: Indirect and Total Effects

Effect	Estimate	Std. Error	z-value	p-value
Indirect Effect (a × b)	-0.027	0.034	-0.798	0.425
Total Effect	0.132	0.031	4.249	<0.001

mediating role within the model was not supported.

T able 6 shows that the indirect effect was not statistically significant, indicating that adoption did not mediate the relationship between barriers and impact. Nevertheless, the total effect remained significant, suggesting that barriers primarily influenced impact through direct pathways within the model."

Table 7: Coefficient of Determination (R^2)

Endogenous Variable	R^2
Adoption Index	0.405
Impact Index	0.034

The structural model exhibited stronger predictive capability for adoption than for impact, with relatively limited variance explained for the latter outcome

The results point to a structure where barriers shape both adoption of sustainable practices and impact outcomes in the built environment sector. Higher barriers reduce adoption, which reflects how financial limits, weak institutional support, limited technical capacity and regulatory constraints restrict implementation. This pattern aligns with sustainability transition explanations that place stronger weight on external constraints than on willingness to adopt. Adoption does not have a significant effect on impact, which suggests that implementation remains partial or weakly integrated into project delivery systems, limiting its ability to translate into measurable improvement. Barriers also show a direct effect on impact, which indicates that constraints affect outcomes even when adoption is present, most likely through inefficiency in execution, delays, reduced quality and coordination challenges. The mediation result confirms that adoption does not serve as a linking pathway between barriers and impact since the indirect effect is not significant, which supports a structure dominated by direct constraint effects. The model explains more variation in adoption than in impact, which suggests that adoption responds mainly to barriers while impact is shaped by broader contextual conditions such as institutional capacity, enforcement strength and technological readiness that were not captured in the model. The pattern supports the view that improving outcomes requires reducing structural and operational constraints rather than focusing only on increasing adoption levels.

CONCLUSION

This study examined the relationships between perceived barriers, adoption of sustainable practices and impact within the built environment sector. The findings show that barriers reduce adoption and also have a direct effect on impact. Adoption does not have a significant effect on impact and no mediation effect is supported. The results indicate that structural and operational constraints play a central role in shaping both behavioural response and outcome performance. This suggests that improving outcomes requires more than increased adoption, since adoption alone does not translate into improved impact when constraints remain in place. Efforts aimed at improving sustainability performance should therefore focus on reducing institutional, financial, technical and regulatory constraints that limit effective implementation. The study is limited by its cross sectional design and the range of variables included in the model. Future work should include additional factors such as institutional capacity, governance quality, technological readiness and enforcement strength to provide a broader explanation of impact formation in sustainable construction.

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