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DRIVERS AND BARRIERS TO THE USE OF ALTERNATIVE CONSTRUCTION MATERIALS IN AFRICA

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Purpose: The deepening housing deficit in Africa appears unmanageable by the current escalating costs of conventional building materials from economic recession. The shortfall is exacerbated by the rising population growth, particularly in Nigeria. Despite the research evidence of the capability of alternative construction materials (ACMs) to replace conventional materials, their use in building construction is established to be low in the country. This study therefore examines the drivers and barriers of ACMs in building construction in Nigeria.
Design/methodology/approach: The study conducts a self-study structured questionnaire survey on building construction professionals. The professionals, the unit of analysis, are purposively sampled. The study area is Nigeria.
Findings: The key drivers to using ACMs include minimization of construction waste, low cost of ACMs, promotion of sustainable development, and energy efficiency. The analysis shows that these variables are significant in facilitating the use of ACMs in the Nigerian building sector. The results also establish an existing correlation between the barriers to the use of ACMs within eight (8) main components. These are cost-related barriers, support-related barriers, design-related barriers, market-related barriers, professional-related barriers, convention-related barriers, social barriers, and policy-related barriers.
Practical implications: The instruments of government support that enhance a large commercial scale production of ACMs and use are expedient to raise the level of confidence of stakeholders on the use of ACMs in Nigeria. Institutions of learning, professional bodies, and technological research and development institutes also have crucial roles to play in the general acceptance of ACMs in building construction.
Originality/value: The study provides information to solving social housing problems towards national economic development and growth.
Keywords: Alternative Construction Materials, Barriers, Drivers, Building, Nigeria.
Category of the paper: Research paper.

1. Introduction

There is a high-rising level of awareness of alternative construction materials (ACMs) in Africa, particularly in South Africa, Ghana, and Nigeria (Masia, Kajimo-Shakantu, Opawole, 2020). Studies establish that ACMs are low-cost, locally available, structurally sound, green, and environmentally friendly (Evison, Kremer, Guiver, 2018). However, the extent of use of ACMs in building construction is rather low in Africa (Opawole, Kajimo-Shakantu, Olapade, 2022). Currently, the housing shortfall in Africa is overwhelming. Nigeria has a housing deficit of 14-16 million, about 3.7 million in South Africa, 1.7 million in Ghana, and an annual demand of up to 250,000 units in Kenya (Habitat for Humanity, 2022). Addy et al. (2020) aver that the economic issues of building production remain the major concern in Africa. Iwuagwu, Iwuagwu (2015) added that the impact of the escalating costs of conventional construction materials (CCM; predominantly adopted for building construction) on housing units' unaffordability in Africa is massive. The status quo of housing deficits in Africa is salvageable, if alternative materials to CCMs are given due consideration. Solving the problem of housing shortfalls through the use of ACMs calls for urgent attention in Africa (Habitat for Humanity, 2022; Iwuagwu, Iwuagwu, 2015).

ACMs have the structural fitness to partially or fully replace conventional materials in building construction, without compromising on quality (Van Deventer et al., 2010). Examples of ACMs include bamboo, bituminous substance, timber, reinforced plastics, tempered glass, fiber-reinforced polymer, Ferro-cement, soil conditioning agent, polyester fibers, palm oil fly ash, structural insulated panel, clay-based materials, waste-based materials (i.e. plastic in concrete, coconut fiber in concrete, waste phosphor-gypsum and natural gypsum in soil block (Zarman et al., 2022; Shubbar et al., 2019; Danso, 2018; Nweke, 2017; Gomez, Raut, 2016; Ede et al., 2015). Other ACMs established to be highly sustainable are aluminum thatch, low emissivity glass windows and doors, solar tiles, cellular lightweight concrete, Sulfo-Aluminate cement, adobe block, earthbags, ceramics, autoclaved aerated concrete, strawbales, low volatile compound paint, grasscloth wallpaper, terrazzo, eco surface, medium density fiberboard, grass pavers, faswell, etc. (Maisia et al., 2022; Opawole et al., 2022; Iwuagwu, Iwuagwu, 2015).

Studies like Van Deventer et al. (2010, 2012) establish that the capabilities of ACMs to emit less greenhouse gases and to technically as well as commercially replace the CCMs are the drivers of their uses in building construction of developed nations. The geopolymer binders of ACMs are composed of fly ash, metallurgical slags, and natural pozzolans characteristics which produce up to 80% lesser carbon emission than OPC. Moreover, ACMs are safe, durable, and cheap in building construction (Magutu, 2015). It is believed that ACMs are cheap because they are locally produced and there is a reduction in the transportation cost to be incurred, unlike the imported materials. Magutu (2015) opines that the use of ACMs in building construction reduces the cost of production and supply of decent low-cost housing units that are affordable to low-income earners. Vejaratnam et al. (2020) claim that the awareness of green materials coupled with the individual beliefs and acceptance of the procurers are crucial drivers to their adoption.

Rather than the environmental benefits of ACMs, the economic effectiveness of ACMs is asserted to be the main driver of their use in developing countries, particularly Africa (Addy et al., 2020). For example, Masia et al. (2020) aver that the operational cost-saving potential of a green building is the strong force that has given impetus to the use of ACMs in South Africa. The lifecycle cost-saving potentials of ACMs are envisaged to allay the fear of the risk-averses in the country. Also, increased demand for office spaces and political incentives are stressed to be the drivers of the use of ACMs in the country. Afunanya, Job (2016) and Gbadebo (2014) stress that the drivers of ACMs in Nigeria are their capabilities to solve socio-economic problems of unemployment and deficient housing spaces, reduce construction time because it is easy to work with, and their cost-effectiveness. Zami (2015) reveals that the drivers for the use of ACMs in Zimbabwe are enhanced technologies, developments in innovative earth construction, public media promotion of earthen construction by stakeholders, the introduction of degree programmes on earth architecture in universities, and organization of training workshops for stakeholders. Addy et al. (2020) reveal that the development of government policies and regulations on green building, and regulating the standardization of green building are the drivers of ACMs in Ghana.

The empirical findings by Simpeh et al (2021) give a suitable taxonomy of the barriers to the practice of green building procurement in South Africa. The barriers are costly green technologies and materials, unaffordability of green building certification, poor data management and motivation system that limited the incorporation of ACMs in building projects, vague regulatory and steering approaches for the implementation of green parameters in building development, scarce professionally skilled human resource to execute green building procurement, and behavior-averse of stakeholders to green building materials. Moreover, Mbambo, Agbola, Olojede (2021) stress that the barriers to ACMs in housing delivery for black South Africans, especially the AV light steel house, are low consumer education and acceptance of ACMs, weak buy-in and marketing of the innovative building by both the private sector and the government, insufficient government subsidies for new entrant suppliers, and lack of synergy between suppliers and contractors.

Addy et al. (2020) identify the barriers to the broader development of housing facilities with ACMs in Ghana as lack of awareness of the materials, lack of educational inclusion, absence of fiscal incentives to motivate professionals and low demand for innovative buildings. The Centre for Affordable Housing Finance in Africa (CAHF, 2019) aver that over 80% of Ghanaians cannot afford the cheapest housing unit which consequently informs the low demand for innovative construction in Ghana. In Malaysia, Samari et al. (2013) reveal the barriers to the adoption of ACMs in building construction to include scarce resources to reduce the upfront cost, project investment risk, low demand for ACMs, high final cost of building development, lack of technology, lack of expertise, and absence of government support. The study by Pradhananga, Elzomor, and Kasabdji (2021) on the barriers to sustainable construction practices in Venezuela stresses that the prevailing unstable economies, monopoly, political cataclysms, and inadequate policies are the impediments to the adoption of ACMs in building construction. Oyewole, Ojutalayo, and Araloyin (2019) establish that the ACM building market is a capital-intensive venture that discourages developers in Nigeria from investing in such a venture. Developers are reluctant to embrace green procurement because the immediate economic benefits of ACMs are not easily achievable, except for the lifecycle cost benefits (Choi, 2009). Also, the building developers insist on the use of CCMs because they are already accustomed to them, and the users are prejudiced against using ACMs in Nigeria (Iwuagwu, Iwuagwu, 2015; Gbadebo, 2014). Table 1 displays some other barriers inhibiting the use of ACMs in building constructions in developing nations.

Table 2.
The barriers to the use ACMs in building construction

Critical barriers	Countries	Authors
Limited resources to cover the upfront cost, investment risk, lack of demand for ACMs, and higher final cost	Malaysia	Samari et al. (2013)
Perceived high initial costs, dearth of knowledge of innovative buildings and technological difficulties, lack of demand and strategies to promote sustainable construction, higher financial cost, poor public awareness and government support, shortfall in the diffusion of knowledge and practice of GB certification, lack of education and awareness, no standard green building tool, limited of expertise, no fiscal incentives from government, limited of research and case studies, more focus on capital costs than on operating cost, lack of eco-labeling for products and materials	Ghana	Opoku, Ayarkwa, Agyekum (2019); Djokoto, Dadzie, Ohemeng-Ababio (2014); Ampratwum et al. (2019); Agyekum,Adinyira,Oppon, (2019); Addy et al. (2020)
Poor knowledge of true investment returns, dearth of knowledge and education of green building, paucity of existing green building projects for sufficient knowledge gaining for designers, reluctant developers/contractors, limited practical knowledge and expertise of building owners and designers, undue overestimation of initial cost of innovative building by estimators, clients' apathy, lack of reliable benchmarking data for performance rating of green building	South Africa	Chan et al. (2018); Bond, Perrett (2012); Darko, Chan (2016)
Reduced commitment from higher management, lack of management support, perceived higher cost of green procurement, lack of government enforcement, high costs, lack of awareness and passive culture, lack of tools and indicators for environmental assessment	India	Mojumder et al. (2022)
Conflicting prejudice by professional builders; lacking resources and technologies; lacking protective legislation for earthen buildings; inaccessibility of credit facilities and insurance cover; lacking policy to minimize CCMs usage; misconception of users and ill-fated cultural belief; lacking academic provisions for training on earthen building construction in universities; lower professional charges from earthen construction; lacking market demand for earthen buildings by users; lacking requisite expertise of professionals and understanding by users	Zimbabwe	Zami (2015)

2. Methods

This study adopts a quantitative research approach using a questionnaire survey to identify the drivers of the use of ACMs and to investigate the barriers to the use of ACMs for building construction in Africa, particularly Nigeria. The questionnaire was well structured and close-ended to enable the respondents to accurately attend to the objectives of the study, while also expressing their practical views from construction experience (Kumar, 2011). The drivers and barriers drawn from the review of similar studies formed section B of the questionnaire design, while the profile of the respondents formed section A of the questionnaire design. The questionnaire was self-administered to professionals from architectural firms, contracting firms, and quantity surveying firms in Lagos State, Nigeria. Lagos is the commercial nucleus of Nigeria, the most populous city in the country having 15.4-24 million population, with the highest rate of urbanization, and the top-ranked State with the highest demand for building infrastructure (Egbo, 2022; Ugochukwu, Chioma, 2015). The State is the nation's construction hub.

The professionals who have been engaged in the design of buildings with ACMs, who have given cost advice on the financial implications of ACMs for building construction, and who have executed building construction with ACMs, were the target population for the study. Since the construction practices and experience with ACMs are not as prevalent as the construction practices and experience with CCMs (Harte, 2017; van Deventer et al., 2010), the professionals who have an awareness of ACMs and have been involved in the use of ACMs for building construction were purposively sampled for the study, to obtain accurate and correct data on the drivers and barriers to the state-of-the-art uses of ACMs in building construction. As a result, the survey captured and retrieved complete responses from nine architects, four builders, one developer, twenty-two engineers, and thirty-one quantity surveyors (QS). These professionals (67) surveyed are the key construction professionals in the construction industry.

The data obtained, on the drivers and barriers variables (see Table 2), from the expert opinions of the professionals, were analyzed by the SPSS statistics v22. Descriptive and inferential statistics were the statistical tools employed for the analysis. The descriptive tools were frequencies, percentages, and mean scores. The variables of drivers and barriers of ACMs were examined using Mean Score (MS) to identify the drivers and barriers that predominate the Nigerian building construction sector. A five-point Likert scale of 5 to 1 ($5 > 4 > 3 > 2 > 1$) was adopted, where the respondents were asked to rank the drivers on a scale of 5 = most important, 4 = more important, 3 = important, 2 = slightly important, 1 = not important. The respondents were asked to rank the barriers on a scale of 5-1; 5 = most critical and 1 = not critical. The mean score calculation was based on the expression (Cheung et al., 2012):

$$\text{MS} = \sum(f \times s)/N \quad (1)$$

where:
"s" is the score given to the drivers and drivers,
"f" is the frequency of each rating (1-5) for each variable, and
"N" is the total number of responses concerning the variables on ACMs.

The inferential statistical tools were the factor analysis, Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett's test of sphericity. The sample size to variable (STV) of the study, STV = 2.75:1, subjected to factor analysis agrees with the adequacy of STV of 2:1 or STV of 3:1 for factor analysis recommended by Glas, Raithel, Essig (2019). Also, the validity of sampling adequacy by the KMO test, KMO of study = 0.63, agrees with the acceptable and good values range of 0.5–1.0 for factor analysis recommended by Kaiser (1974).

Table 2.
Drivers and barriers of ACMs

	Drivers		Barriers
D1	Minimization of construction waste	B1	Lack of funding and insufficient capital
D2	Low cost of ACMs as against the high cost of CCMs	B2	Poor policy environment
D3	Promotion of sustainable development	B3	Low market demand for ACMs
D4	Education on the green benefits of ACMs	B4	Lack of technical expertise
D5	Energy efficiency	B5	Unavailable cost data on benefits of ACMs
D6	Increase of client's awareness about ACMs and demand	B6	Unwillingness and lack of support from end users
D7	Locally manufactured and available	B7	Lack of performance evaluation indicator
D8	Noise insulation benefits of ACMs	B8	Risks in adopting new practices
D9	Low cost of maintenance	B9	Low technological innovations
D10	Massive investment in building technology	B10	Lack of green building codes
D11	Affordability	B11	Unwillingness of professionals
D12	Non-toxicity of material	B12	Low public awareness of ACMs
D13	Increasing building regulatory pressure	B13	Lack professional knowledge
D14	Water efficiency of ACMs	B14	Ignorance of green benefits of ACMs
D15	Increase of clients' awareness about the cost benefits of ACMs	B15	Lack of regulation
D16	Rapidly renewable	B16	Conservativeness of management to CCMs
D17	Political support and increasing incentives	B17	Low-scale availability of ACMs
D18	Promotion of cultural heritage	B18	Cultural belief on the less aesthetic appearance of ACMs
D19	Recyclability	B19	High maintenance cost
D20	Energy efficiency and user's wellbeing	B20	Ineffective application from immature technology
		B21	Lack of government incentives
		B22	Complexity of design that supports ACMs
		B23	Lack of organizational structure

3. Results

3.1. The respondents' profile

Table 3 displays the background information about the respondents on their professional and academic qualifications, years of construction work experience, and the number of projects they have executed and/or been involved in. The respondents captured are key construction professionals from both contracting and consulting firms. About 46.3% of the respondents are quantity surveying, 32.8% are engineers, 13.4% are architects and 6% are builders. The average construction work experience of the respondents is estimated at approximately eleven years. The respondents have handled the construction of buildings with ACMs at approximately twelve projects. This profile information about the respondents authenticates the adequacy of information obtained for this study.

Table 3.
Demographic information of respondents

Profile	Attribute	Frequency	%
Profession of respondents	Architect	9	13.4
	Quantity surveyor	31	46.3
	Engineers	22	32.8
	Builder	4	6.0
	Developer	1	1.5
Highest academic qualification of respondents	OND/HND	10	14.9
	B.SC/B.Tech	45	67.2
	M.Sc/M.Tech	12	17.9
Year of construction work experience	1-5	23	34.3
	6-10	16	23.9
	11-15	10	14.9
	16-20	9	13.4
	21-25	9	13.4
Number of projects executed	1-5	16	23.9
	6-10	18	26.9
	11-15	8	11.9
	16-20	12	17.9
	21-25	13	19.4
	Total	67	100.0

3.2. Drivers of ACMs in building construction in Nigeria

The study reveals that up to 19 drivers are important in boosting the use of ACMs in building construction in the country (Table 4). The MS values of the drivers range from $3.45 \leq MS \leq 3.99$. Just one of the drivers is revealed by the study to be more important in fostering the use of ACMs in building construction in the country. The more important driver is the minimization of construction waste (MS = 4.10). A test of significant difference among the drivers rated by the professionals was conducted using the Kruskal Wallis H test. A significance value range of $p \leq 0.000$ is known to be of significant difference, while $p > 0.005$ is of no significant difference (Kaiser, 1974 in Field, 2009). The result indicates that there exists no significant difference in the ranking of the level of importance of the drivers to the use of ACMs in building construction in Nigeria by all the professionals, with a significance range of $0.983 \leq p \leq 0.065$.

Table 4.
The drivers of ACMs in building construction in Nigeria

Drivers	All professionals		Architects		Quantity surveyors		Engineers		Builders		Kruskal Wallis h test
	MS	R	MS	R	MS	R	MS	R	MS	R	
D1	4.10	1	4.44	1	4.00	2	4.09	3	4.00	7	0.712*
D2	3.99	2	4.22	2	4.06	1	4.00	6	2.50	20	0.065*
D3	3.93	3	4.11	5	3.97	3	3.91	8	3.25	15	0.983*
D4	3.91	4	3.89	7	3.55	9	4.27	1	4.50	1	0.106*
D5	3.78	5	3.67	11	3.52	11	4.05	5	4.50	1	0.264*
D6	3.73	6	4.22	2	3.74	4	3.41	19	4.00	7	0.171*
D7	3.73	7	4.22	2	3.74	4	3.55	17	3.25	15	0.293*
D8	3.73	8	3.44	15	3.48	12	4.14	2	3.75	11	0.202*
D9	3.73	9	3.78	9	3.71	6	3.77	11	3.25	15	0.560*
D10	3.69	10	3.56	14	3.68	8	3.64	13	4.25	3	0.841*
D11	3.69	11	3.78	9	3.71	6	3.50	18	4.00	7	0.748*
D12	3.60	12	3.33	17	3.48	12	3.95	7	3.00	19	0.301*
D13	3.58	13	3.44	15	3.23	19	4.09	3	4.25	3	0.092*
D14	3.57	14	3.89	7	3.48	12	3.59	15	3.25	15	0.861*
D15	3.55	15	3.67	11	3.55	9	3.64	13	3.50	13	0.606*
D16	3.54	16	4.00	6	3.39	16	3.41	19	4.25	3	0.489*
D17	3.52	17	3.33	17	3.19	20	3.86	9	4.25	3	0.122*
D18	3.51	18	3.67	11	3.26	17	3.77	11	3.50	13	0.692*
D19	3.49	19	3.33	17	3.26	17	3.82	10	3.75	11	0.472*
D20	3.45	20	3.22	20	3.42	15	3.59	15	4.00	7	0.290*

**significant difference, *no significant difference, R = Rank.

3.3. Barriers to ACMs in building construction in Nigeria

The study reveals that up to 9 barriers are more critical barriers militating against the use of ACMs in Nigerian building construction (Table 5). The MS values of the more critical barriers range from $4.00 \leq MS \leq 4.75$. About 14 barriers are revealed by the study to critically militate against the use of ACMs in building construction in the country, having the MS values range of $3.00 \leq MS \leq 3.75$. A test of significant differences among the barriers rated by the professionals was conducted using the Kruskal Wallis H test. A significance value range of $p \leq 0.000$ is known to be of significant difference, while $p > 0.005$ is of no significant difference (Kaiser, 1974 in Field, 2009). The result indicates that there exists no significant difference in the ranking of the critical levels of 22 barriers to the use of ACMs in building construction in Nigeria by professionals, with a significance range of $0.949 \leq p \leq 0.171$. However, there exists a significant difference of $p = 0.021$ in the ranking of the critical level of the barrier of poor policy environment by the professionals in the country.

Table 5.
The barriers to ACMs in the Nigerian building construction sector

Barriers	All professionals		Architects		Quantity surveyors		Engineers		Builders		Kruskal Wallis H test
	MS	R	MS	R	MS	R	MS	R	MS	R	
B1	4.75	1	4.09	1	4.33	1	3.97	2	4.00	2	0.544*
B2	4.00	6	3.88	2	3.44	12	3.68	13	4.27	1	0.021**
B3	4.50	2	3.88	2	3.78	3	3.81	6	3.86	4	0.582*
B4	4.25	3	3.88	2	3.56	8	4.13	1	3.55	19	0.191*
B5	4.00	6	3.84	5	3.56	8	3.97	2	3.68	12	0.549*
B6	4.00	6	3.82	6	3.44	12	3.97	2	3.68	12	0.589*
B7	3.50	12	3.82	6	3.56	8	3.81	6	3.95	3	0.708*
B8	4.25	3	3.75	8	3.78	3	3.74	10	3.59	18	0.631*
B9	3.75	10	3.75	8	3.89	2	3.71	11	3.68	12	0.730*
B10	4.00	6	3.73	10	3.11	18	3.81	6	3.86	4	0.263*
B11	3.00	21	3.69	11	3.22	17	3.81	6	3.82	9	0.549*
B12	4.25	3	3.69	11	3.67	6	3.87	5	3.27	21	0.313*
B13	3.50	12	3.66	13	2.89	22	3.71	11	3.86	4	0.286*
B14	3.75	10	3.64	14	3.33	15	3.68	13	3.64	15	0.602*
B15	3.50	12	3.64	14	3.00	20	3.65	15	3.86	4	0.185*
B16	3.25	18	3.61	16	3.56	8	3.65	15	3.64	15	0.992*
B17	3.25	18	3.57	17	3.44	12	3.39	23	3.86	4	0.403*
B18	3.25	18	3.55	17	3.67	6	3.58	18	3.55	19	0.949*
B19	3.00	22	3.54	19	3.33	15	3.55	20	3.64	15	0.605*
B20	3.50	12	3.51	20	3.11	18	3.48	21	3.77	10	0.495*
B21	3.00	23	3.43	21	3.78	3	3.58	18	3.09	23	0.303*
B22	3.50	12	3.43	21	3.00	20	3.61	17	3.27	21	0.398*
B23	3.50	12	3.43	21	2.44	23	3.45	22	3.77	10	0.171*

**significant difference, *no significant difference, R = Rank

A further inferential statistical analysis of the ranked barriers of ACMs from Table 5 were carried out using the factor analysis. This is important to establish the correlation adequacy among the variables. Table 7 displays the result of the principal component analysis (PCA) by the orthogonal rotation (varimax) with Kaiser normalization, conducted on the initial 23 barriers. The PCA correlated the barriers by reducing them to eight (8) components. The KMO measure of sampling adequacy (Table 6) verifies the sampling adequacy for the analysis at KMO = 0.63 (good, according to Hutcheson, Sofroniou, 1999 in Field, 2009). The KMO values for the barrier variables are > 0.60, which is well above the acceptable limit of 0.50 (Kaiser, 1960). The Bartlett's test of sphericity was adopted to check for the appropriateness and suitability of the data for factor analysis. The Bartlett's test of sphericity, x^2 (276) = 767.65, $p = 0.000$ (Table 7), indicates that the correlations between the barrier variables were sufficiently large for the PCA. The initial analysis run to obtain eigenvalues for the individual barriers gave values >1 (this is > the Kaiser's criterion of 1; Kaiser, 1960). Cumulatively, the 8 components explain a 72.99% of the variance between the barriers. Interpreting factor loadings > 0.50 is averred adequate to underscore the substantial importance of a component (Anyanwu, 2013). Therefore, the factor loading of 0.50 is used as a cut-off point for the variables of the barriers of ACMs for each component. The scree plot displayed in Figure 1 also shows the inflexions that justifies retaining the 8 components. Thus, given the sample size adequacy, the exceedance of the Kaiser's criterion, and the convergence of the scree plot on the 8th component, the number of the 8 components are established as the barriers impeding the use of ACMs for building construction in Nigeria.

Table 6.
Factor loading on barriers to ACMs, KMO, and Bartlett's test on barriers of ACMs

Factor	**Factor loading**	**Total**	**% of variance**	**Cumulative %**
Component 1: Cost-related barriers		**6.172**	**25.716**	**25.716**
Lack of government incentives	0.675			
Low-scale availability of ACMs	0.638			
High maintenance cost	0.763			
Lack of professional knowledge	0.526			
Component 2: Support-related barriers		**2.692**	**11.215**	**36.931**
Lack of funding or insufficient capital	0.586			
Low technological innovations	0.595			
Unwillingness and lack of support from the end users	0.785			
Lack of green building codes	0.562			
Component 3: Design-related barriers		**1.979**	**8.244**	**45.175**
Lack of organizational structure	0.682			
Complexity of design that supports ACMs	0.676			
Ineffective application from immature technology	0.760			
Component 4: Market-related barriers		**1.610**	**6.710**	**51.885**
Low market demand for ACMs	0.671			
Lack of performance evaluation indicators	0.739			
Lack of technical expertise	0.703			
Component 5: Professional-related barriers		**1.587**	**6.612**	**58.497**
Unwillingness of professionals	0.682			
Unavailable cost data on benefits of ACMs	0.816			
Component 6: Convention-related barrier		1.227	5.113	63.610
Conservativeness of management to CCMs	0.770			
Low public awareness of ACMs	0.638			
Component 7: Social barrier		**1.151**	**4.796**	**68.406**
Ignorance of the green benefits of ACMs	0.812			
Cultural belief on less aesthetic appearance of ACMs	0.706			
Component 8: Policy-related barrier		**1.100**	**4.585**	**72.991**
Poor policy environment	0.806			
Lack of regulation	0.796			
KMO and Bartlett's test on barriers of ACMs				
Kaiser-Meyer-Olkin measure of sampling adequacy				0.627
Bartlett's test of sphericity				
Approx. chi-square				767.651
df				276
Sig. (*p*)				0.000

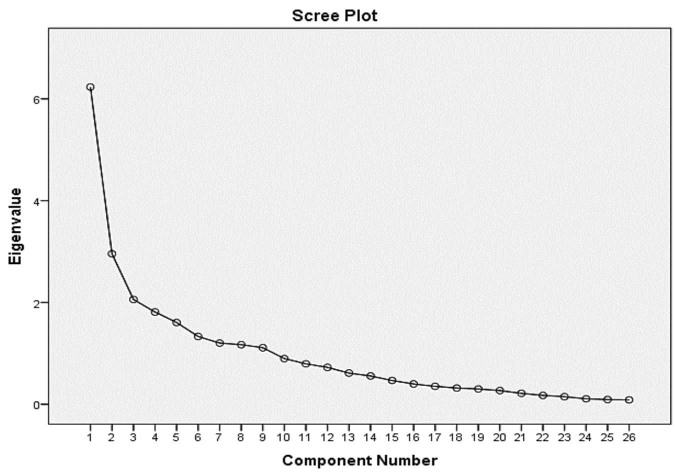

Figure 1. The scree plot showing the barrier components.

4. Discussion

The study reveals the generic nature of the drivers for the use of ACMs in building construction in Africa. This is because all the drawn drivers of ACMs in Africa from reviewed literature confirm their importance in Nigeria as well, from the blinded expert judgment of the professionals by their rankings. All the professionals indicate the importance of the 20 drivers of ACMs in building construction in the country with the MS values range of $3.45 \leq MS \leq 3.99$ (Table 4). These drivers for the use of ACMs in Nigeria corroborate their suitability for building construction in Africa as they also pertain to South Africa, Zimbabwe, and Ghana (Masia et al., 2020; Addy et al., 2020; Zami, 2015); although the peculiarities of these individual countries attribute varying degree of importance to the identified drivers. The study establishes no variance in the importance of the identified drivers to boost ACMs in building construction in Nigeria because there exists no significant difference in the expert judgment of the professionals ($0.983 \leq p \leq 0.065$). However, the minimization of construction waste (D1) maintains consistency in its rating ($4.00 \leq MS \leq 4.44$) by all the professionals as a more important driver of ACMs in the country. The highest index of no existence of significant difference ($p = 0.065$) in the rating of D2 (high cost of CCMs) as an important driver of ACMs confirms the assertion by Addy et al. (2020), that the economic benefits derivable from the use of ACMs constitute a high impetus to their use in building construction in Africa. Other important drivers of ACMs that maintain their consistence across the line of expert judgment by each of the professionals are low cost of maintenance (D9: $3.25 \leq MS \leq 3.78$), non-toxicity of materials (D12: $3.00 \leq MS \leq 3.95$), water efficiency of ACMs (D14: $3.25 \leq MS \leq 3.89$), increasing awareness of cost benefits (D15: $3.50 \leq MS \leq 3.67$), promotion of cultural heritage (D18: $3.26 \leq MS \leq 3.77$), and recyclability (D19: $3.26 \leq MS \leq 3.82$).

This study establishes that nine (9) barriers are more critical barriers militating against the use of ACMs in building construction in Nigeria. These are lack of funding and insufficient capital (B1: MS = 4.75); poor policy environment (B2: MS = 4.00); low market demand for ACMs (B3: MS = 4.50); lack of technical expertise, risks in adopting new practices, and low public awareness of ACMs (B4, B8, B12: MS = 4.25 respectively); unavailable cost data on benefits of ACMs, unwillingness and lack of support from the end users, and lack of green building codes (B5, B6, B10: MS = 4.00 respectively). The remaining 14 barriers are revealed to be critical barriers of ACMs, having the MS values range of $3.00 \leq MS \leq 3.75$. The study gives singular evidence of a significant difference in the expert judgments of all the professionals to the barrier of poor policy environment (B2: $p = 0.021$). However, no evidence of significant differences ($0.949 \leq p \leq 0.171$) in the critical level of the remaining 22 barriers is underscored by all the professionals. Conversely, the quantity surveyors argue that the barriers of lack of professional knowledge of ACMs (B13: MS = 2.89) and lack of organizational structure (B23: MS = 2.44) have an insubstantial influence on the use of ACMs in building construction in Nigeria.

The study further establishes the inferential statistical evidence of the existing correlation between the barriers of ACMs by principal component analysis, which reduced and grouped the 23 barriers into eight (8) main components. The components are cost-related barriers, support-related barriers, design-related barriers, market-related barriers, professional-related barriers, convention-related barriers, social barriers, and policy-related barriers.

4.1. Component 1: Cost-related barriers

The first component is highly correlated with cost-related barriers. This component explains 25.72% of the total variance of the barriers of ACMs in building construction in Nigeria. The cost-related barriers have variable loadings of barriers with a score range of $0.526 \leq 0.763$. The highest-ranked barrier in this component is high maintenance cost, with a factor loading of 0.763. The component is also clustered with a lack of government incentives, low-scale availability of ACMs, and lack of professional knowledge with factor loadings of 0.675, 0.638, and 0.526 respectively. The high maintenance cost of housing facilities built with ACMs is a critical barrier to the demand for ACMs by building owners in Nigeria. The inference for this is drawn from the low technological innovations in the branding of ACMs for building construction and the ineffective application of ACMs from immature technology in the country. The high maintenance cost of ACMs in housing facilities in the country disagrees with the operational cost savings of green buildings reinforced by Masia et al. (2020) in South Africa. This calls for technological advancement for innovative solutions in the production of ACMs. The absence of government incentives to encourage the production of ACMs in Nigeria is inferred as the reason for the low-scale production and availability of ACMs for building construction in the country.

4.2. Component 2: Support-related barriers

The second component accounts for 11.22% of the total variance of the barriers of ACMs for building construction in Nigeria. The component is highly correlated with support-related barriers, having the barrier variable loadings of $0.562 \leq 0.785$. The factor loadings of the component are lack of funding or insufficient capital, low technology innovations, unwillingness and lack of support from end users, and lack of green building codes with their factor loadings of 0.586, 0.595, 0.785, and 0.562 respectively. The construction market force is controlled by the demand and supply of building products. The demand for building products being determined by the needs of the end-users influences what is supplied. When the end users or building clients (individuals, corporate bodies, or governments) do not demand for ACMs from their unawareness or conservativeness in favor of CCMs, a critical barrier is therefore constituted. The lack of green building codes that are compatible with the construction of buildings with ACMs is also a critical barrier, which is an indication of the absence of government support for ACMs in building construction in the country. The large-scale manufacture of ACMs for the construction of housing facilities that are fit for habitation requires intensive capital, therefore insufficient capital by the manufacturers (SMEs) is a critical barrier to the use of ACMs in the country. This challenge faced by SMEs in the country is an update to the findings by Gbadebo (2014) on SMEs' production of ACMs in Nigeria. Insufficient capital is also deemed to influence the use of inappropriate technology which is unattractive to the end users. These barriers are replicas of the barriers of limited resources to cover upfront costs and lack of demand for ACMs in Malaysia, as well as poor government support in Ghana (Samari et al., 2013; Opoku et al., 2019).

4.3. Component 3: Design-related barriers

The third component is highly correlated with design-related barriers and explains about 8.24% of the total variance of the barriers to the use of ACMs for building construction in Nigeria. The component has the factor loadings of ineffective application from immature technology (0.760), lack of organizational structures to support ACMs (0.682), and complexity of design that supports ACMs (0.676). The lack of organizational support for ACMs and the complexity of design (to be produced by architects and engineers) suggest the perceptions of the contracting management team and professionals that the use of ACMs in building construction is a disruptive technology (Evison et al., 2018). This is because these stakeholders have already been accustomed to the uses of CCMs for several years, therefore restructuring their system partially or completely in compliance with the use of ACMs to accommodate changes seems unpalatable. The immature technology for ACMs brings about a lack of clarity in design tools to be adopted by the designers and thus constitutes a serious problem of complexity of design for building construction with ACMs in the country.

4.4. Component 4: Market-related barriers

The fourth component accounts for 6.71% of the total variance of the barriers of the use of ACMs in building construction in Nigeria. The components of this factor are low market demand for ACMs, lack of performance evaluation indicators for ACMs, and lack of technical expertise with factor loadings of 0.671, 0.739, and 0.703 respectively. This component is highly correlated with market-related barriers. The non-commercial scale of production of ACMs in the country impedes increased demand for ACMs and their inability to compete with the current larger scale of OPC production and availability in the construction market. Unlike the existing green building standard rating of 25% - 50% for assessment projection of water and energy efficiency in South Africa (Masia et al., 2020), the standard rating for green assessment projection and evaluation indicator of the performance of ACMs in Nigeria is inaccessible. The low level of educational inclusion in the training of ACMs by construction-related programmme in higher institutions of learning gives rise to the lack of technical expertise.

4.5. Component 5: Professional-related barriers

The fifth component is highly correlated with professional-related barriers. The component explains up to 6.61% of the total variance of the barriers to the use of ACMs in building construction in Nigeria. The component is clustered with unavailable cost data on the benefits of ACMs (0.816) and unwillingness of the professionals (0.682). The dearth of data banks for construction-related matters is a common phenomenon in Nigeria (Babatunde et al., 2015). Therefore, the lack of available cost data that will inform the stakeholders about the cost benefits associated with the use of ACMs for building construction during the buildings' lifecycle, to influence the use of ACMs is a critical barrier in the country. The unwillingness of the professionals is inferred to be attributed to the confidence in the use of CCMs from their age-long use in the industry (Hart, 2017; van Deventer et al., 2010). The professionals are the key players in the construction industry, therefore their reservations about the use of ACMs in building construction pose a serious threat to the wider acceptance of ACMs for construction and the practices of sustainable building technology in the country.

4.6. Component 6: Convention-related barriers

The sixth component is highly correlated with convention-related barriers and accounts for 5.11% of the total variance of the barriers of ACMs in building construction in Nigeria. The component is grouped with conservativeness of management to CCMs (0.770) and low public awareness of ACMs (0.638). Although the awareness of the public about the use of ACMs and the constructability of housing facilities with ACMs is rising in the country (Opawole et al., 2022), they are reluctant to embrace the reality of the full use of ACMs in building construction. This is because the contracting managements are customarily used to the CCMs and they are not ready to alter their organizational arrangement to embrace the new change (that is, the use of ACMs). This barrier gives an empirical validation to the cause of the low frequency of use of such ACMs as strawbales, plastic bottle waste rice husk, Ferro-cement, faswell, etc., in Nigeria, being asserted by Opawole et al. (2022).

4.7. Component 7: Social barriers

The seventh component is correlated with social barriers. The component explains 4.80% of the total variance of the barriers to the use of ACMs in building construction in Nigeria. The component is grouped with ignorance of the green benefits of ACMs (0.812) and cultural belief in the less aesthetic appearance of ACMs (0.706). While the developed countries are empirically convinced and driven to the use of ACMs for sustainable building construction because of the environmental, eco-friendly, and green benefits of ACMs, the developing countries, particularly Nigeria are not well informed. This is evident by the established barrier of ignorance of the green benefits of ACMs by the construction players. The cultural belief that the façade of housing facilities constructed with ACMs is unattractive when compared to those constructed with CCMs is revealed by this study to be a critical barrier to the use of ACMs in building construction in the country.

4.8. Component 8: Policy-related barriers

The eighth component is correlated with policy-related barriers and it accounts for 4.59% of the total variance to the use of ACMs in building construction in Nigeria. The component is grouped with a poor policy environment and lack of regulation, with factor loadings of 0.806 and 0.796 respectively. Poor policy environment and absence of regulation to encourage the construction stakeholders to fully embrace the use of ACMs in building construction are common phenomena in the practices of sustainable building construction in some developing countries (Pradhananga et al., 2021); unlike South Africa which operates the green policy by the Green Building of South Africa (Masia et al., 2020). Research findings establish that the enabling green policies and government regulations in support of the use of ACMs for building construction are the government instruments that have successfully encouraged the technological advancement in the supply of ACMs and the use of ACMs in building construction in developed countries. This is evident in the growth of ACMs, i.e. mass timber construction technology, in New Zealand, Australia, and some other European countries. Therefore, for ACMs technology to thrive in the Nigerian construction industry, the government instruments adopted in the the developed nations for ACM have to be adapted.

5. Summary

This study establishes the importance of 20 drivers of ACMs in building construction in Nigeria. These are minimization of construction waste, low cost of ACMs as against the high cost of CCMs, promotion of sustainable development, education on the green benefits of ACMs, energy efficiency from ACMs, low cost of maintenance, among others. These drivers are very germane to enable Nigeria to keep up with the growth of sustainable development in building construction of other developing countries, like South Africa. Empirical inferences drawn from this study establish the prevailing critical barriers of ACMs in building construction in Nigeria. These are cost-related barriers, support-related barriers, design-related barriers, market-related barriers, professional-related barriers, among others. Rather than concentrating on the waste minimization potentials and the economic values of ACMs in building construction as confirmed by this study, the eco-friendly benefits of the ACMs should be given more priority, to enable the country properly conform with the global Net-Zero Carbon Emission agenda of the Sustainable Development Goal (SDG) goals by 2050 (Zaman et al., 2022).

The government is both the major employer/client in the construction industry and the major regulator of construction policy. Therefore, for ACMs technology to thrive in the Nigerian construction industry, all the three tiers of governments (i.e. federal government, state government, and local government) have to be awakened to their roles in formulating and implementing green policies and regulations that comply with the use of ACMs in building construction. The policies and regulations are expedient because they will encourage construction professionals, clients and suppliers to accept the ACMs technology and application in building construction. This study recommends that the government formulate green building codes and enact regulations in compliance with ACMs for building design and construction, introduce government incentives to suppliers of ACMs to encourage the production of commercial scale of green building materials, reduce tax tariffs for ACMs-inclined building projects construction by developers and contractors, and use work experience in past ACMs-inclined projects and evidence of technical expertise in ACMs application as selection criteria for bidders of government projects. The study also recommends that the governments give directives for the design of building plans of mass housing development schemes in compliance with ACMs, and fund research and development to generate innovative solutions to the production and use of ACMs in building construction in the country.

The diffusion of these government instruments for the use of ACMs in building construction in the country will build the confidence of construction professions, clients and supplies. This will also eliminate the barriers of the complexity of design of ACMs-inclined buildings for the architects, engineers and builders; foster effective production of cost data for green buildings by quantity surveyors; increase local availability of ACMs at larger commercial scales; raise the market demands for ACMs by building owners, and facilitate a boom in the delivery of housing development projects with ACMs by developers and/contractors. Thus, this study concludes that the results of this research work will bring about practical realities of increased number of home owners, increased gross domestic products (GDP) of the country, and increased national economic growth of Nigeria.

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