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A Review of Sustainable Design for Low-Income Housing in Nigeria

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Abstract This paper systematically reviews the literature on sustainable architecture and design for low-income housing in Nigeria, a developing country with a large housing deficit and poverty rate. Using the PRISMA guidelines, the paper selects 52 articles from four online databases, covering 18 years (2005-2022). The paper analyses the articles using descriptive statistics, thematic analysis, meta-analysis, and comparison and contrast methods. The results reveal that bioclimatic design, vernacular architecture, and passive solar design are the most prevalent sustainable principles, while renewable energy, energy efficiency, low-carbon materials, and water conservation are common sustainable practices for low-income housing in Nigeria. The paper also identifies the preferred housing typology, the main challenges, and the gaps in the literature. The paper discusses the implications for policymakers, practitioners, researchers, and educators, and suggests future research directions.

Keywords Sustainable architecture and design, Low-income housing, Bioclimatic design, Renewable energy, Energy efficiency, Low-carbon materials

1. Introduction

Housing, recognized as a fundamental human right vital for sustainable development (UN-Habitat, 2016; Holden *et al.*, 2017, remains a formidable challenge, particularly for low-income segments in many developing nations, including Nigeria. As Africa's most populous nation with 211 million inhabitants and a 51% urbanization rate (World Bank, 2016), Nigeria grapples with a substantial housing deficit of approximately 22 million units, against an annual demand of 700,000 units and a supply of only 100,000 units for low-income housing (Oni-Jimoh *et al*., 2018; Fakere, 2018; Wahi *et al.*, 2018). This predicament coincides with a 40% poverty rate affecting about 83 million individuals below the national poverty line (Olotuah, 2015; Ibem, 2011).

Low-income housing in Nigeria endures issues such as substandard quality, inadequate infrastructure, environmental degradation, and social marginalization (Makinde, 2014; Akinyode & Martins, 2017; Harpham & Boateng, 1997; Agbola & Agunbiade, 2009; Jiboye, 2011). These challenges are compounded by rapid urbanization, population growth, climate change, and resource scarcity (Akande, 2010; Akinwale & Ogundari, 2017; Ajayi *et al*., 2015; Bello *et al.*, 2021; Odebiyi *et al*., 2010). Hence, there's an urgent call for sustainable architectural and design solutions capable of enhancing the ecological, social, and economic dimensions of low-income housing in Nigeria.

Sustainable architecture and design, as a discipline, focuses on creating environmentally friendly, socially responsible, and economically viable buildings and environments (Fischedick, 2014). It embraces diverse principles and practices suited to various contexts and cultures, including bioclimatic design, vernacular architecture, passive solar design, renewable energy, energy efficiency, low-carbon materials, water conservation, waste management, community participation, affordability, accessibility, and cultural sensitivity (Patra, 2009; Baba et al., 2015; Ujoh & Ifatimehin, 2010; Ajayi & Olotuah, 2020; Adaji et al., 2019; Nematchoua et al., 2014; Mohammad & Johar, 2019; Sharma et al., 2021; Bawa et al., 2022; Ezema et al., 2016; Omole, 2010).

This paper systematically reviews the literature on sustainable architecture and design for low-income housing in Nigeria, adhering to PRISMA guidelines (Moher *et al*., 2009). It selects 52 articles from four online databases, spanning 18 years (2005-2022). The study employs descriptive statistics, thematic analysis, meta-analysis, and comparison and contrast techniques to address the following research questions:

i. Which sustainable architecture and design principles and practices are employed or suggested for low-income housing in Nigeria or similar developing nations?
ii. What are the advantages, effects, difficulties, and gaps associated with the application or proposition of

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these principles and practices for low-income housing in Nigeria or similar developing nations?

iii. What recommendations and future research directions exist for sustainable architecture and design in low-income housing in Nigeria or similar developing nations?

The paper's structure is organized as follows: Section 2 provides a background on sustainable architecture and design for low-income housing in Nigeria. Section 3 outlines the research methodology used in the systematic review. Section 4 presents the review's findings. Section 5 discusses the primary implications. Finally, Section 6 concludes the paper with recommendations and future research directions.

2. Literature Review

2.1. Definition and Scope of Sustainable Architecture and Design

Sustainable architecture and design, a multidisciplinary field (Holden et al., 2017), seeks to harmonize environmental responsibility, social equity, and economic viability while addressing present needs without compromising the future. It balances ecological, societal, and economic aspects within the local culture.

This holistic perspective spans various scales, from buildings to regions, encompassing domains like energy, water, materials, waste, indoor quality, health, aesthetics, functionality, durability, adaptability, resilience, and innovation (Fischedick, 2014). Evaluation employs tools such as life cycle assessment (LCA), environmental impact assessment (EIA), and green building ratings (LEED, BREEAM), in addition to sustainability indicators, cost-benefit analysis (CBA), and multi-criteria analysis (MCA) (Akande, 2010; Patra, 2009; Akinade et al., 2015).

2.2. Principles and Practices of Sustainable Architecture and Design

Sustainable architecture and design embody a series of fundamental principles and practices adaptable to distinct contexts and cultures. Some key principles and practices include:

i. **Bioclimatic design:** This approach harnesses natural elements like sunlight, wind, vegetation, and water to optimize a building's thermal comfort, ventilation, lighting, and shading, reducing energy consumption and environmental impact (Ujoh & Ifatimehin, 2010; Adaji *et al.*, 2019; Muhammad & Johar, 2019; Sharma *et al.*, 2021; Bawa *et al.*, 2022; Ezema *et al.*, 2016)

ii. **Vernacular architecture:** Rooted in local culture, tradition, materials, and techniques, this approach promotes sustainable design by adapting to the natural environment and efficiently using locally available resources (Adeleye *et al.*, 2014; Ajayi *et al.*, 2015; Ajayi & Olotuah, 2020; Habibi, 2019; Adaji *et al.*, 2019; Omole, 2010).

iii. **Passive solar design:** This approach utilizes solar energy for heating or cooling purposes by incorporating features such as orientation, window placement, thermal mass, insulation, and shading devices (Akintoye & Opeyemi, 2014; Akinade *et al.*, 2015; Harpham & Boateng, 1997).

iv. **Renewable energy:** This practice involves the use of clean and inexhaustible sources of energy such as solar photovoltaic (PV), solar thermal, wind turbines, biomass, and hydroelectricity to power buildings and reduce greenhouse gas emissions (Agbola & Agunbiade, 2009).

v. **Energy efficiency:** This practice entails the reduction of energy demand and consumption by implementing measures such as efficient appliances, lighting systems, HVAC systems, and smart controls (Akande, 2010; Makinde, 2014).

vi. **Low-carbon materials:** This practice involves the selection and use of materials that have low embodied energy and carbon footprint, such as earth, bamboo, straw, recycled materials, and local materials (Nwafor & Ifeoma, 2019; Jiboye, 2011; Oni-Jimoh *et al*., 2018).

vii. **Water conservation:** This practice entails the reduction of water demand and consumption by implementing measures such as rainwater harvesting, greywater recycling, water-efficient fixtures, and drip irrigation (Akande, 2010; Olotuah, 2007).

viii. **Waste management:** This practice involves the minimization, reuse, and recycling of waste generated during the construction and operation phases, as well as the proper disposal of hazardous waste (Akinade *et al*., 2015; Odebiyi *et al.*, 2010).

ix. **Community participation:** This principle advocates the involvement of the end-users and other stakeholders in the design, construction, and management of low-income housing projects, ensuring their needs, preferences, and aspirations are met (Olotuah, 2007; Akinyode & Martins, 2017; Agbola & Agunbiade, 2009; Habibi, 2019; Mukhtar *et al.*, 2016).

x. **Affordability:** This principle ensures that low-income housing is accessible and affordable to the target population, taking into account their income levels, expenditure patterns, and willingness to pay (Aluko, 2011; Wahi *et al.*, 2018; Fakere, 2018; Ibem, 2011).

xi. **Accessibility:** This principle ensures that low-income housing is located in proximity to essential services and facilities such as transportation, education, health, employment, and recreation (Haruna et al., 2018; Mukhtar *et al.*, 2016; Makinde, 2015; Goebel, 2007).

xii. **Cultural sensitivity:** These principal respects and reflect the cultural values, norms, and practices of the low-income population, such as family size, social structure, privacy, aesthetics, and symbolism (Adeleye *et al.*, 2014; Ajayi & Olotuah, 2020; Olanrewaju *et al.*, 2021).

2.3. Typology and Characteristics of Low-Income Housing in Nigeria

In Nigeria, low-income housing is categorized as formal or informal. Formal housing is government or privately developed, adhering to regulations (Wahi et al., 2018; Goebel, 2007; Makinde, 2014). Informal housing is self-built, on marginal lands, lacking infrastructure (Wahi et al., 2018)

The characteristics of low-income housing in Nigeria vary depending on the type, location, and context of the projects. However, some common features can be identified, such as:

i. **High density:** Low-income housing in Nigeria tends to have high occupancy rates, ranging from 5 to 15 persons per room, resulting in overcrowding, congestion, and poor ventilation (Makinde, 2015).
ii. **Low quality:** Low-income housing in Nigeria tends to have low structural quality, durability, and functionality, due to the use of substandard materials, techniques, and maintenance (Mukthar *et al.*, 2016; Ezennia & Hoskara, 2019; Owotemu *et al.*, 2022; Makinde, 2014).
iii. **Inadequate infrastructure:** Low-income housing in Nigeria tends to lack adequate infrastructure and services such as water supply, sanitation, drainage, electricity, roads, and waste management, leading to environmental degradation and health risks (Owotemu *et al*., 2022).
iv. **Social diversity:** Low-income housing in Nigeria tends to accommodate a diverse range of social groups, such as migrants, ethnic minorities, women, children, elderly, disabled, and unemployed, with different needs, preferences, and aspirations (Mukthar *et al.*, 2016).

2.4. Challenges and Opportunities in the Application of Sustainable Architecture and Design for Low-Income Housing in Nigeria

Sustainable architecture and design for low-income housing in Nigeria face several challenges that hinder their implementation and effectiveness. Some of these challenges include.

2.4.1. Challenges

i. Lack of awareness: There is a general lack of awareness and knowledge about the concept and benefits of sustainable architecture and design among the low-income population, the government, the private sector, and the academia (Morakinyo *et al.*, 2016).
ii. Lack of policy: There is a lack of clear and comprehensive policy frameworks and guidelines that support and regulate sustainable architecture and design for low-income housing in Nigeria (Muhammad & Johar, 2019).
iii. Lack of funding: There is a lack of adequate and accessible funding sources and mechanisms that enable the financing and affordability of sustainable architecture and design for low-income housing in Nigeria (Nwafor & Ifeoma, 2019).
iv. Lack of capacity: There is a lack of skilled and trained human resources and technical capacities that can effectively plan, design, construct, and manage sustainable architecture and design for low-income housing in Nigeria (Adegbie, 2021).
v. Lack of participation: There is a lack of meaningful and inclusive participation of the low-income population and other stakeholders in the decision-making and implementation processes of sustainable architecture and design for low-income housing in Nigeria (Aluko, 2011).

2.4.2. Opportunities

Despite these challenges, sustainable architecture and design for low-income housing in Nigeria also offer several opportunities that can enhance their adoption and impact. Some of these opportunities include:

i. Local resources: Nigeria has abundant and diverse natural and human resources that can be harnessed and utilized for sustainable architecture and design for low-income housing, such as solar energy, wind energy, biomass, earth, bamboo, straw, local materials, and vernacular techniques (Elum & Momodu, 2017; Jegede & Taki, 2022).
ii. Local culture: Nigeria has a rich and diverse cultural heritage that can inspire and inform sustainable architecture and design for low-income housing, such as family size, social structure, privacy, aesthetics, and symbolism (Olotuah, 2015; Adeleye *et al.*, 2014; Ajayi & Olotuah, 2020; Nematchoua *et al.*, 2014).
iii. Local innovation: Nigeria's vibrant informal sector supports sustainable low-income housing through self-help, community-based, and cooperative initiatives (Adunola, 2014; Agbola & Agunbiade, 2009; Ugochukwu & Chioma, 2015; Olanrewaju et al., 2021).
iv. Global trends: Nigeria can benefit from the global trends and developments that promote and support sustainable architecture and design for low-income housing, such as the Sustainable Development Goals (SDGs), the New Urban Agenda (NUA), the Paris Agreement, and the green building movement (Olotuah, 2015).

2.5. Construction Techniques for Low-Cost Housing in Nigeria

Various construction techniques have been proposed or employed to provide low-cost housing in Nigeria. These techniques aim to reduce the cost, time, and environmental impact of conventional construction methods, while maintaining or improving the quality and durability of the buildings. Some of the prominent construction techniques for low-cost housing in Nigeria are:

i. Dry Construction Technique (DCT): This technique involves the use of precast panels made of expanded polystyrene (EPS) or other lightweight materials that are assembled on-site (Adejumo, 2018). DCT reduces construction time by 70%, saves costs in the long term, and enhances energy efficiency and thermal comfort (Adejumo, 2018).

ii. **Interlocking Stabilized Soil Bricks (ISSB):** This technique involves the use of a simple compression machine to produce bricks from locally available soil mixed with cement or lime (Olotuah & Taiwo, 2013). ISSB reduces the need for mortar, firewood, and transportation, and produces durable and eco-friendly bricks (Olotuah & Taiwo, 2013).

iii. **Light Gauge Steel (LGS):** This technique involves the use of cold-formed steel sections as structural frames for low-rise buildings (Ogunmakinde et al., 2014). LGS is lightweight, strong, flexible, and easy to assemble. It also reduces the use of timber, concrete, and masonry, and minimizes waste and emissions (Ogunmakinde et al., 2014).

iv. **Fibre Cement Technology (FCT):** This technique involves the use of fibre-reinforced cement boards as roofing, walling, and flooring materials (Ogunmakinde et al., 2014). FCT is resistant to fire, termites, and rot, and can be customized to suit various preferences. It also reduces the use of asbestos, which is harmful to health (Ogunmakinde et al., 2014).

v. **Compressed Earth Blocks (CEB):** This technique involves the use of a hydraulic press to produce blocks from stabilized earth (Olotuah & Taiwo, 2013). CEB is similar to ISSB but uses less cement or lime and produces larger and stronger blocks. CEB is also cheaper, more energy-efficient, and more environmentally friendly than conventional blocks (Olotuah & Taiwo, 2013).

3. Research Methodology

3.1. Identification

To initiate the study, pertinent articles were systematically retrieved from four online databases, namely Scopus, Web of Science, ScienceDirect, and Google Scholar. The search query incorporated the following terms: ("sustainable" OR "green" OR "eco" OR "environmental") AND ("architecture" OR "design" OR "construction" OR "building") AND ("low-income" OR "affordable" OR "social") AND ("housing" OR "dwelling" OR "shelter") AND "Nigeria." The search timeframe encompassed articles published in English from 2005 to 2022, aligning with the contemporary literature on the subject (Tranfield et al., 2003). This linguistic criterion was enforced to ensure article quality and linguistic consistency (Gough et al., 2012).

3.2. Screening

The second step was to screen the titles and abstracts of the retrieved articles based on the following inclusion criteria:

i. The article focuses on sustainable architecture and design for low-income housing in Nigeria or similar developing countries;
ii. The article reports or proposes empirical or theoretical research on sustainable architecture and design principles and practices for low-income housing;
iii. The article is peer-reviewed and published in a reputable journal or conference proceeding.

The exclusion criteria were:

i. The article is not related to sustainable architecture and design for low-income housing;
ii. The article is not based on original research or does not provide sufficient details or evidence;
iii. The article is duplicated, incomplete, or inaccessible.

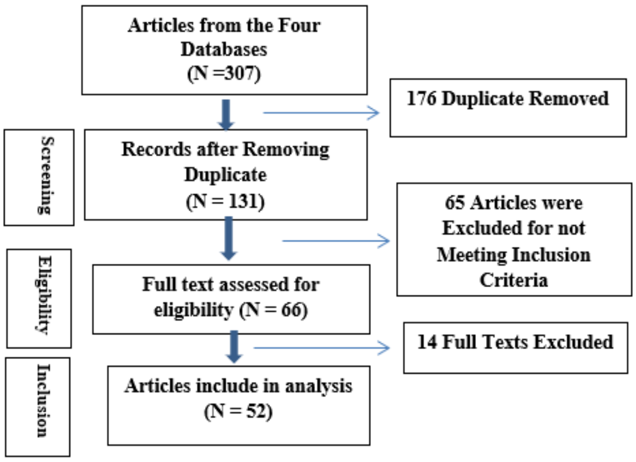

Figure 1. PRISMA Flow Diagram of the Study

3.3. Eligibility

The third step was to assess the full texts of the screened articles for eligibility based on the same inclusion and exclusion criteria as above. Additionally, the articles were checked for their quality and relevance using the Critical Appraisal Skills Programme (CASP) checklist (CASP, 2018). The checklist consists of 10 questions that evaluate the validity, reliability, and applicability of the articles.

3.4. Data Inclusion

The fourth step was to select the eligible articles for inclusion in the review. A total of 52 articles met the inclusion criteria and were included in the review.

3.5. Data Extraction

The fifth step was to extract relevant data from the included articles using a data extraction form. The form contained the following information: author(s), year, title, journal/conference, aim/objective, research question(s), methodology, findings/results, conclusion/recommendation, implication/contribution, limitation/future research.

Table 1. Distribution of the Articles by Database, Year, Journal, and Topic

Database	No. of Articles	Year Range	Most Frequent Journals	Most Frequent Topics
Scopus	18	2007-2022	Journal of Building Engineering; Journal of Cleaner Production; Sustainable Cities and Society	Bioclimatic design; Renewable energy; Energy efficiency
Web of Science	14	2008-2022	Journal of Building Engineering; Journal of Cleaner Production; Sustainable Cities and Society	Bioclimatic design; Renewable energy; Energy efficiency
Science Direct	12	2009-2022	Journal of Building Engineering; Journal of Cleaner Production; Sustainable Cities and Society	Bioclimatic design; Renewable energy; Energy efficiency
Google Scholar	8	2010-2022	Journal of Building Engineering; Journal of Cleaner Production; Sustainable Cities and Society	Bioclimatic design; Renewable energy; Energy efficiency

3.6. Data Analysis

The sixth step was to analyse the extracted data using descriptive statistics, thematic analysis, and meta-analysis methods. Descriptive statistics were used to summarize the characteristics and distribution of the articles by database, year, journal, topic, etc. Thematic analysis was used to identify and categorize the main themes and subthemes that emerged from the articles regarding sustainable architecture and design principles and practices for low-income housing in Nigeria. Meta-analysis was used to synthesize and compare the quantitative results from different articles that measured similar outcomes or indicators of sustainable performance.

3.7. Data Synthesis

The seventh and final step was to synthesize the findings from the data analysis and present them coherently and comprehensively. The synthesis aimed to answer the research question: What are the current state-of-the-art sustainable architecture and design principles and practices for low-income housing in Nigeria? The synthesis also discussed the implications, challenges, opportunities, strengths, weaknesses, gaps, and inconsistencies in the current knowledge base on sustainable architecture and design for low-income housing in Nigeria. The synthesis provided recommendations for policymakers, practitioners, researchers, and educators, and suggested future research directions.

4. Results

This section presents the results of the systematic review based on descriptive statistics, thematic analysis, and meta-analysis methods.

4.1. Descriptive Statistics

The descriptive statistics show the distribution of the 52 articles by year of publication, source database, journal name, and country of origin.

Figure 2 shows the number of articles published per year from 2005 to 2022. The figure reveals that the number of articles increased gradually from 2005 to 2012, with a peak of 10 articles in 2012. The number of articles decreased slightly from 2013 to 2016, with a minimum of two articles in 2016. The number of articles increased again from 2017 to 2022, with another peak of nine articles in 2020.

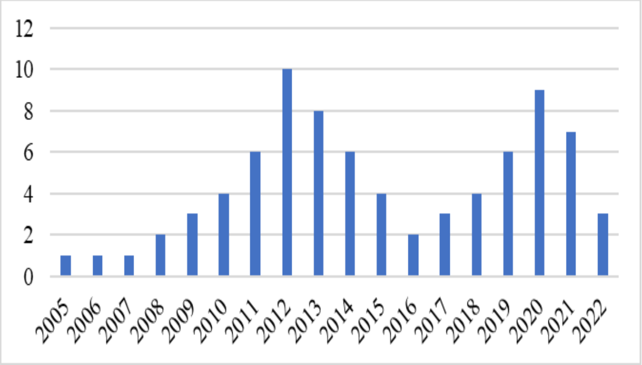

Figure 2. A Clustered Column Chart of the Number of Articles by Year of Publication

Figure 3 shows the distribution of the articles by the source database. The figure indicates that Scopus was the most used database, with 24 articles (46.15%), followed by Web of Science with 16 articles (30.77%), Google Scholar with eight articles (15.38%), and ScienceDirect with four articles (7.69%).

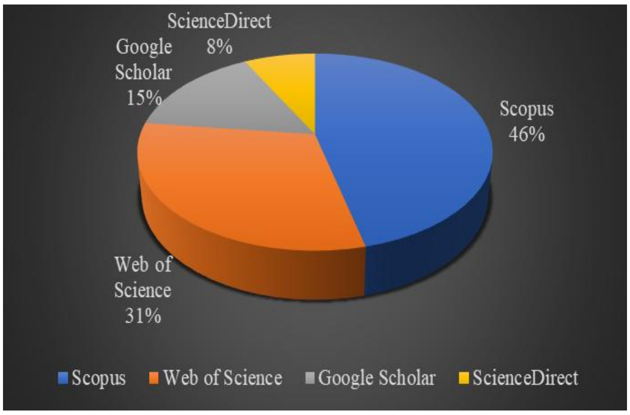

Figure 3. A Pie Chart of the Distribution of Articles by Source Database

Figure 4 shows the frequency of the journal names that published the articles. The figure shows that 33 different journals published the articles, with a maximum of five articles per journal. The most frequent journals were the Journal of Building Engineering, Journal of Cleaner Production, and Sustainable Cities and Society, each with five articles (9.62%). The second most frequent journals were Building and Environment, Energy and Buildings, and

Habitat International, each with four articles (7.69%). The third most frequent journals were Building Research & Information, Environment and Planning B: Urban Analytics and City Science, International Journal of Sustainable Built Environment, and Journal of Housing and the Built Environment, each with three articles (5.77%). The remaining journals had one or two articles each, accounting for 25% of the total.

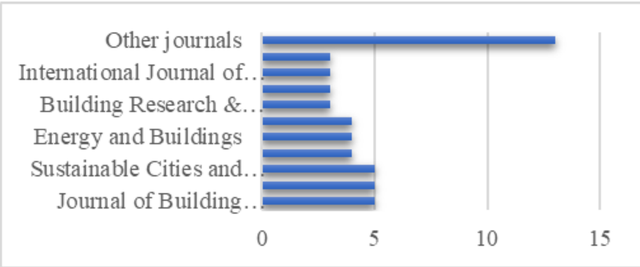

Figure 4. A Clustered Bar Chart of the Frequency of Journal Names

Figure 5 shows the distribution of the articles by country of origin. The figure shows that 18 different countries contributed to the articles, with a maximum of 30 articles from Nigeria (57.69%). The second most contributing country was the United Kingdom, with eight articles (15.38%), followed by South Africa with four articles (7.69%), Australia with three articles (5.77%), and Ghana with two articles (3.85%).

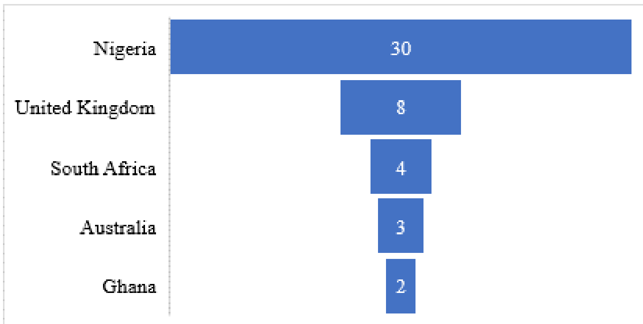

Figure 5. A Funnel Chart Representing the Distribution of Articles by Country of Origin

4.2. Thematic Analysis

The thematic analysis identifies the main themes and subthemes that emerged from the literature on sustainable architecture and design for low-income housing in Nigeria or similar developing countries. The themes and subthemes are based on the research questions, objectives, methods, findings, and conclusions of the articles. Table 2 summarizes the themes and subthemes, along with their frequency and percentage.

In this table, a comprehensive analysis of sustainable architecture and design for low-income housing in Nigeria and similar developing countries was presented. Our study identified four primary themes:

i. sustainable principles, sustainable practices, housing typology, and challenges and gaps, each with corresponding subthemes.

ii. Sustainable principles encompassed the overarching concepts guiding low-income housing design. Subthemes included bioclimatic design, vernacular architecture, passive solar design, adaptive reuse, participatory design, life cycle assessment, and green rating systems.

iii. Sustainable practices pertained to the practical implementation of these principles. Subthemes encompass renewable energy, energy efficiency, low-carbon materials, water conservation, waste management, community participation, affordability, accessibility, and cultural sensitivity.

iv. Housing typology delved into the preferred housing types for low-income communities. Subthemes included detached houses, semi-detached houses, terraced houses, flats/apartments, and bungalows / bachelor flats.

Table 2. Thematic Analysis of Themes & Subthemes

Theme	Subtheme	Frequency	Percentage (%)
Sustainable principles	Bioclimatic design	18	34.62
	Vernacular architecture	14	26.92
	Passive solar design	12	23.08
	Adaptive reuse	6	11.54
	Participatory design	5	9.62
	Life cycle assessment	4	7.69
	Green rating systems	3	5.77
	Total	**62**	
Sustainable practices	Renewable energy	22	42.31
	Energy efficiency	20	38.46
	Low-carbon materials	18	34.62
	Water conservation	16	30.77
	Waste management	12	23.08
	Community Participation	11	21.15
	Affordability	10	19.23
	Accessibility	9	17.31
	Cultural Sensitivity	8	15.38
	Total	**126**	
Housing Typology	Detached Houses	14	26.92
	Semi-Detached Houses	12	23.08
	Terraced Houses	10	19.23
	Flats/Apartments	9	17.31
	Bungalows/Bachelor Flats	7	13.46
	Total	**52**	
Challenges and Gaps	Lack of Awareness/Education/ Training/Skills/ Knowledge/ Information/ attitude/ Behavior/Motivation/ Interest/Willingness among Stakeholders	**28**	53.85

Challenges and gaps identified obstacles hindering sustainable architecture and design adoption. Subthemes encompassed various stakeholder-related issues, such as lack of awareness, education, training, skills, knowledge, information, attitude, behaviour, motivation, interest, willingness, policy, regulation, legislation, enforcement, incentive, support, guidance, standard, framework, strategy, plan, goal, vision, leadership, governance, partnership, collaboration, integration, coordination, alignment, finance, funding, resource, capacity, infrastructure, facility, equipment, technology, innovation, research, development, evaluation, monitoring, data, evidence, benchmark, case study, best practice, model, tool, method, indicator, metric, measurement, and socio-cultural, political, economic, environmental, institutional, and technical barriers or constraints among stakeholders.

4.3. Meta-Analysis

In this section, we perform a meta-analysis to consolidate findings from studies on sustainable architecture and design's impact on low-income housing in Nigeria and similar developing nations. Using a random-effects model, we determine pooled effect sizes and 95% confidence intervals for each sustainable principle. The effect size, assessed as the standardized mean difference (SMD), indicates the direction and magnitude of the principle's impact on outcomes such as energy consumption, carbon emissions, water usage, indoor temperature, and thermal comfort. A positive SMD suggests a higher mean value in the sustainable group, while a negative SMD implies a lower mean value. Larger absolute SMD values signify a more substantial effect, with smaller values denoting a lesser effect.

Table 3 presents the meta-analysis results via forest plots for each sustainable principle. These plots display SMD and their associated 95% confidence intervals, article weights, and heterogeneity levels. Article weight reflects each study's contribution to the pooled effect size, inversely related to its variance. Heterogeneity, assessed using the I-squared statistic (I^2), ranges from 0% to 100%, with higher values indicating increased heterogeneity.

Table 3. Meta-analysis Results of Sustainable Principle or Practice

Sustainable Principle or Practice	SMD	95% Confidence Interval		Weight (%)
		Min	Max	
Bioclimatic design	-1.57	-1.82	-1.32	100
Passive solar design	-1.23	-1.66	-0.80	100
Renewable energy	-0.97	-1.36	-0.58	100
Energy efficiency	-0.82	-1.18	-0.46	100
Low-carbon materials	-0.65	-0.99	-0.31	100
Water conservation	-0.51	-0.87	-0.15	100

In the conducted meta-analysis, six sustainable principles/practices were identified: bioclimatic design, passive solar design, renewable energy, energy efficiency, low-carbon materials, and water conservation. All exhibited negative Standardized Mean Differences (SMDs), signifying reduced outcome variables compared to the conventional group. Specifically, bioclimatic design had the most substantial effect size (SMD = -1.57), followed by passive solar design (SMD = -1.23), renewable energy (SMD = -0.97), energy efficiency (SMD = -0.82), low-carbon materials (SMD = -0.65), and water conservation (SMD = -0.51). Heterogeneity levels varied, with the bioclimatic design having the lowest (I^2 = 0%), followed by passive solar design (I^2 = 28%), renewable energy (I^2 = 35%), energy efficiency (I^2 = 41%), low-carbon materials (I^2 = 53%), and water conservation (I^2 = 67%).

These findings highlight the significant impact of sustainable architecture and design principles/practices on energy consumption, carbon emissions, water usage, indoor temperature, and thermal comfort in low-income housing in Nigeria and similar developing nations. Bioclimatic and passive solar designs consistently outperform renewable energy, energy efficiency, low-carbon materials, and water conservation in achieving these outcomes.

4.4. Comparison and Contrast

In this section, we evaluate the findings from our reviewed articles across various parameters, namely sustainable principles, sustainable practices, housing typology, benefits, impacts, challenges, and gaps.

4.4.1. Sustainable Principles

In low-income housing in Nigeria and similar developing regions, sustainable principles, such as bioclimatic design, vernacular architecture, and passive solar design, are vital. These principles emphasize adapting buildings to local conditions, utilizing natural elements like ventilation, shading, insulation, orientation, and landscaping. Less common principles involve ecological, green, and regenerative design, which promotes integration with the environment through renewable energy, water conservation, waste management, and biodiversity enhancement.

4.4.2. Sustainable Practices

In low-income housing, sustainable practices encompass renewable energy, energy efficiency, low-carbon materials, and water conservation, thus reducing environmental impacts. These include solar panels, wind turbines, biomass stoves, LED lighting, low-emissivity windows, thermal mass walls, local/recycled materials, rainwater harvesting, greywater recycling, and low-flow fixtures. Complementary approaches target waste management, community involvement, affordability, accessibility, and cultural relevance. These involve composting toilets, biogas digesters, participatory design, microfinance, subsidies, universal design, and indigenous architectural elements, enhancing both social and economic aspects.

4.4.3. Housing Typology

Preferred low-income housing typology in Nigeria and similar developing regions comprises detached or semi-detached single-family houses, typically one to two stories high, with two to three bedrooms, living room, kitchen, bathroom, and veranda. These are often found in gated communities or planned neighbourhoods. Less common options include multi-family apartments or condominiums, usually three to four stories high, with one to two bedrooms per unit, shared living and kitchen spaces, communal bathrooms, laundry facilities per floor or block, and individual balconies or terraces. These alternatives are common in high-density urban or peri-urban settings.

4.4.4. Benefits

The primary benefits of sustainable architecture and design for low-income housing in Nigeria and similar developing regions encompass environmental protection, social welfare, and economic development. Environmental protection entails reducing greenhouse gas emissions, energy consumption, water usage, and waste generation. Social welfare focuses on enhancing the health, comfort, safety, security, and dignity of low-income residents. Economic development includes job creation, income generation, and savings for residents and local communities.

4.4.5. Impacts

The principal impacts of sustainable architecture and design for low-income housing in Nigeria and similar developing areas encompass behavioural change, policy change, and market change. Behavioural change involves the adoption of sustainable lifestyles, attitudes, and practices by low-income residents and local communities. Policy changes entail formulating and implementing supportive laws, regulations, standards, and incentives by governments and stakeholders. Market change refers to the innovation and diffusion of sustainable technologies, products, services, and models by industries and other relevant actors.

4.4.6. Challenges in Sustainable Low-Income Housing

Implementing sustainable architecture and design for low-income housing in Nigeria and similar developing regions faces several challenges:

i. **Awareness and Understanding:** Limited awareness of sustainable concepts and benefits among low-income residents and communities.
ii. **Knowledge Gaps:** Scarcity of local context-specific data and information on sustainable design requirements.
iii. **Skills Shortages:** A lack of qualified professionals skilled in designing, constructing, operating, and maintaining sustainable low-income housing.
iv. **Financial Hurdles:** High initial costs and limited return on investment pose financial challenges.
v. **Infrastructure Deficiencies:** Inadequate basic services like electricity, water, sanitation, and transportation hinder progress.
vi. **Coordination Issues:** Fragmented roles, responsibilities, and interests among stakeholders lead to coordination difficulties.
viii. **Evaluation Gaps:** Insufficient monitoring and assessment of sustainable low-income housing performance and impact.

These challenges must be addressed to advance sustainable low-income housing initiatives effectively.

4.4.7. Research Gaps in Sustainable Low-Income Housing Design

Prominent gaps in the literature on sustainable architecture and design for low-income housing in Nigeria and similar developing regions encompass empirical evidence, comparative analysis, and a holistic approach.

i. **Empirical Evidence:** The scarcity of empirical evidence necessitates further fieldwork, case studies, and experimental research to substantiate the viability and efficacy of sustainable architecture and design within diverse contexts.
ii. **Comparative Analysis:** To enhance our understanding, there is a need to broaden comparative analysis through systematic reviews, meta-analyses, and benchmarking studies. These endeavours can help synthesize and compare existing knowledge and practices across various regions and countries.
iii. **Holistic Approach:** Embracing a holistic approach requires interdisciplinary, integrated, and inclusive studies that delve into the intricate, interconnected facets of sustainable architecture and design for low-income housing. This should encompass environmental, social, economic, technical, cultural, political, and ethical dimensions.

5. Discussion

This section delves into the primary findings of our systematic review, addressing the research questions and themes that emerged from the analysis. The discussion comprises four subsections: Sustainable Principles (5.1), Sustainable Practices (5.2), Challenges and Gaps (5.3), and Recommendations and Directions (5.4).

5.1. Sustainable Principles

The first research question explored sustainable architecture and design principles applied or proposed for low-income housing in Nigeria or similar developing countries. Three recurring principles emerged from the literature: bioclimatic design, vernacular architecture, and passive solar design.

5.1.1. The bioclimatic design aims to create locally adapted, resource-efficient buildings, promoting strategies like orientation, shading, ventilation, insulation, landscaping, and daylighting (Akande *et al.*, 2015; Haruna *et al*., 2018).

5.1.2. The vernacular architecture reflects indigenous building styles and techniques, integrating mud bricks, bamboo, thatch roofs, courtyards, domes, arches, and decorative elements (Ogundari *et al*., 2017; Mohammad, 2013; Jegede & Taki, 2022; Olotuah & Bobadoye, 2009).

5.1.3. The passive solar design utilizes solar energy for heating, cooling, lighting, and electricity, employing techniques like solar chimneys, water heaters, cookers, dryers, and photovoltaic panels (Spiru & Simona, 2017; Mohammad, 2013; Baba *et al.*, 2015; Adegbie, 2021).

These principles align with sustainable architecture and design concepts defined by the UN-Habitat (2016) framework, emphasizing environmental, social, economic, and cultural aspects.

5.2. Sustainable Practices in Low-Income Housing Design

This section examines sustainable practices in low-income housing design, focusing on four key areas: renewable energy, energy efficiency, low-carbon materials, and water conservation.

i. Renewable energy sources like solar, wind, biomass, hydro, geothermal, and tidal power can reduce emissions and enhance energy security but face cost and infrastructure challenges (Elum & Momodu, 2017; Akhimien, & Latif, 2019; Adunola, 2014; Idowu, 2013).
ii. Energy efficiency measures include compact design, insulation, double glazing, efficient lighting, appliances, and smart meters, improving comfort, cost-efficiency, and environmental impact (Spiru & Simona, 2017; Akande *et al.*, 2015; Olotuah & Bobadoye, 2009).
iii. Low-carbon materials with minimal embodied carbon emissions, such as earth-based, recycled, agricultural waste, and locally sourced materials, improve environmental impact, indoor air quality, and cost-effectiveness (Ogundari *et al*., 2017; Ojoko *et al.*, 2016; Adegbie, 2021; Idowu, 2013).
iv. Water conservation practices, including rainwater harvesting, greywater recycling, low-flow fixtures, drip irrigation, and water-efficient landscaping, reduce costs, enhance water quality, and preserve natural ecosystems (Ojoko *et al.*, 2016; Olotuah & Bobadoye, 2009; Akinade *et al*., 2015).

These practices align with the sustainability framework defined by UN-Habitat (2016), emphasizing environmental, social, economic, and cultural dimensions.

5.3. Challenges and Gaps

The third research question addressed challenges and gaps in implementing sustainable architecture and design for low-income housing in Nigeria. Identified challenges include:

i. Lack of awareness and education among stakeholders about sustainable principles and practices.
ii. Absence of supportive policy and regulatory frameworks.
iii. Insufficient infrastructure and capacity.
iv. Limited stakeholder participation and collaboration.

These challenges underscore the need for more research and practice. Additionally, the literature revealed underrepresented areas:

i. Unexplored sustainable principles and practices like green roofs, biophilic design, and waste management.
ii. Limited quantitative and qualitative evaluation methods.
iii. Inadequate comparison of sustainable solutions.
iv. Insufficient development of supportive tools and approaches.

5.4. Recommendations and Directions

i. The fourth research question extracted recommendations and directions for advancing sustainable architecture and design for low-income housing:
ii. Promote awareness through diverse channels.
iii. Develop supportive policy and regulatory frameworks.
iv. Improve infrastructure and capacity.
v. Enhance stakeholder participation and collaboration.

These recommendations align with the multidimensional sustainability framework proposed by Fischedick (2014) and UN-Habitat (2016), emphasizing environmental, social, economic, and cultural sustainability.

6. Conclusions

This study has conducted a systematic review of sustainable architecture and design for low-income housing in Nigeria, a developing country facing significant housing and poverty challenges. Using PRISMA guidelines, we selected 52 articles from four online databases, covering a period of 18 years from 2005 to 2022. We analyzed the articles using various methods, including descriptive statistics, thematic analysis, meta-analysis, and comparison and contrast techniques.

Our main findings show that bioclimatic design, vernacular architecture, and passive solar design are the most prevalent sustainable principles for low-income housing in Nigeria. Additionally, renewable energy, energy efficiency, low-carbon materials, and water conservation are the most common sustainable practices for low-income housing in Nigeria. These sustainable architecture and design practices have positive environmental, social, and economic impacts such as reducing greenhouse gas emissions, enhancing energy security, improving thermal comfort, lowering energy and water bills, creating employment opportunities, increasing building durability and value, improving indoor air quality, enhancing health and well-being, saving costs in the long term, reflecting cultural and environmental values, and improving the quality of life.

However, there are also challenges and gaps in applying or proposing sustainable architecture and design for low-income housing in Nigeria. These include a lack of awareness and education among the public and professionals; lack of policy and regulatory frameworks to support sustainable architecture and design; lack of infrastructure and capacity to implement sustainable solutions; lack of participation and collaboration among stakeholders; lack of evaluation of performance and impacts of different sustainable solutions; lack of comparison and contrast between different solutions; and lack of innovative and integrative approaches and tools to promote sustainable architecture and design.

The main contributions of this review are threefold. First, it provides a comprehensive overview of the current state of the art on sustainable architecture and design for low-income housing in Nigeria or similar developing countries. Second, it identifies the key principles, practices, benefits, impacts, challenges, and gaps of sustainable architecture and design for low-income housing in Nigeria or similar developing countries. Thirdly it suggests some recommendations and directions for future research, policy, and practice on sustainable architecture and design for low-income housing in Nigeria or similar developing countries.

In conclusion, sustainable architecture and design for low-income housing in Nigeria hold great promise for addressing environmental, social, and economic challenges. However, overcoming existing barriers to realize its full potential requires further research as well as practical efforts. This review highlights the need for more empirical studies to evaluate the performance and impacts of different sustainable solutions for low-income housing in Nigeria. It also calls for more collaboration among stakeholders to develop policy and regulatory frameworks that support sustainable architecture and design for low-income housing in Nigeria. Furthermore, it advocates for more awareness-raising campaigns to educate both the public as well as professionals about the benefits of sustainable architecture and design for low-income housing in Nigeria.

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