Human-Centred Generative AI for Affordable Housing Design in Nigeria Through an Architect-led Lifecycle Framework

Tajudeen O. Ajayi[1*]; Oluwafunmilayo A. Akinniyi[2]; Yomi M. D. Adedeji[3]

[1] Department of Architectural Technology, The Federal Polytechnic, Ado-Ekiti, Nigeria

[2] Department of Architecture, Elizade University, Ilara-Mokin, Nigeria

[3] Department of Architecture, Federal University of Technology, Akure, Nigeria

***Corresponding Author**

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ABSTRACT

Affordable housing in Nigeria requires architectural solutions that combine spatial efficiency, climate responsiveness, buildability, adaptability, maintainability and affordability in use. This critical structured narrative review examines how generative artificial intelligence (GenAI) can support architect-led but multidisciplinary affordable-housing design when combined with Building Information Modelling (BIM), conventional building-performance evaluation and post-occupancy learning, including digital-twin functions where technically and economically justified. Searches completed on 30 July 2026 used Scopus and Google Scholar for principal discovery, supplemented by targeted publisher-platform and institutional searches. The substantive analytical corpus comprises 43 peer-reviewed publications; review-methodology papers and policy, standards, legal and governance sources are interpreted separately. Evidence was coded across GenAI-specific option generation, conventional generative/parametric design, spatial efficiency, unit/block/site design, BIM information coordination, building-performance simulation, post-occupancy evaluation (POE), digital-twin applications, affordability, liveability and responsible AI. The synthesis indicates that GenAI is most defensible as a constrained exploratory option-generation layer whose outputs require independent architectural, statutory, performance and constructability verification; BIM supports information coordination and traceability rather than automatic validation; and POE provides the baseline lifecycle-learning mechanism, with digital twins representing an optional higher-maturity layer. Human-centredness is operationalised through household and resident evidence at briefing, option evaluation and post-occupancy stages, while accountable professional judgement remains explicit. The article proposes a six-stage lifecycle framework, Nigerian implementation-readiness conditions, an illustrative comparative pilot scenario and testable indicators for empirical validation against conventional design workflows.

Keywords: generative artificial intelligence, affordable housing, architectural design, Building Information Modelling, Nigeria.

INTRODUCTION

Affordable housing in Nigerian cities involves interacting questions of quantity, cost, spatial quality and liveability. Nigerian housing research identifies land and infrastructure constraints, construction-cost pressures, limited finance and low household incomes, while residential studies show that dwelling quality, adaptability, services and neighbourhood conditions also shape housing outcomes (Ezennia & Hoskara, 2019; Ibem & Aduwo, 2013; Makinde, 2014; Ogundipe et al., 2024). For affordable-housing architecture, the design problem is therefore not simply to minimise floor area or first cost, but to reduce avoidable spatial and construction inefficiencies while retaining usability, privacy, accessibility, environmental performance and long-term habitability.

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International housing and climate agendas reinforce this multidimensional conception of adequacy. Sustainable Development Goal 11 links adequate, safe and affordable housing with inclusive and resilient settlements, while building-sector and climate evidence place energy, emissions and climate response within the housing-quality agenda (Intergovernmental Panel on Climate Change, 2022; International Energy Agency, 2025; United Nations Department of Economic and Social Affairs, n.d.; United Nations Environment Programme, 2026; United Nations Human Settlements Programme [UN-Habitat], 2026). Accordingly, this review treats affordable housing as a combination of initial and recurring costs, spatial adequacy, location and services, maintainability, environmental performance, adaptability and longer-term usability (Ezennia & Hoskara, 2019; Mulliner et al., 2013; UN-Habitat, 2026).

Human-centred digital practice treats computational systems as augmentation rather than autonomous design authorities. In affordable housing, this requires both accountable professional judgement and meaningful representation of household needs, user diversity and lived experience throughout briefing, option evaluation and post-occupancy learning. GenAI may support early option generation and spatial exploration; BIM may provide a structured environment for coordinating building information; conventional simulation may test selected performance outcomes; and digital-twin approaches may connect maintained asset information with operational evidence where the required data and organisational capacity exist (Becerik-Gerber et al., 2012; Boje et al., 2020; Deng et al., 2021; Jang et al., 2025; Li et al., 2024). These functions are complementary but technologically distinct.

For conceptual precision, this review distinguishes GenAI from related computational methods. GenAI refers to learned generative models that create or transform design-related content. Generative design refers more broadly to computational generation and search within explicit objectives and constraints, while parametric design varies geometry or relationships through defined parameters. Building-performance simulation is treated as physics-based analysis, and BIM as information modelling and management rather than AI. This distinction is important because floor-plan generation, adjacency reasoning, massing and multi-objective exploration in the literature draw on several method classes, not all of which constitute contemporary GenAI (Hu et al., 2020; Nagy et al., 2017; Nauata et al., 2020; Yan et al., 2026).

Within the reviewed corpus, direct empirical evidence integrating GenAI, BIM, performance analysis and operational feedback within completed affordable-housing projects is limited, and no Nigerian study demonstrates an end-to-end GenAI-assisted affordable-housing workflow. International computational studies are therefore treated as evidence of methods and technical possibilities rather than direct evidence of effectiveness under Nigerian household, climatic, cultural, regulatory, construction and affordability conditions. The review addresses this gap by connecting computational option generation with independent architectural verification, multidisciplinary checking, resident evidence and performance-in-use learning, while preserving the distinction between transferable methods and locally demonstrated outcomes (Jang et al., 2025; Ogundipe et al., 2024; Pinti et al., 2022).

Five questions guide the review: (1) how can GenAI expand architectural alternatives for affordable housing without undermining dignity and contextual fit; (2) how can BIM make shortlisted alternatives coordinated, measurable and traceable; (3) how can post-occupancy evidence—and, where justified, digital-twin functionality—inform subsequent architectural briefs, prototypes and decisions; (4) what human-centred governance principles are required for responsible GenAI use in Nigerian architectural practice; and (5) under what data, organisational and cost conditions are GenAI, BIM and digital-twin functions proportionate and feasible for affordable-housing delivery in Nigeria?

The article proposes an architect-led but multidisciplinary lifecycle design logic. GenAI supports constrained option generation; BIM supports information coordination and traceability; conventional simulation supports performance evaluation; POE provides the baseline feedback mechanism; and digital-twin functionality represents a higher-maturity operational layer where justified by data quality, governance, organisational capacity and lifecycle benefit. The framework foregrounds household briefing, site and climate response, spatial organisation, accessibility, buildability, affordability, performance verification, resident validation and learning from occupation.

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Review Design and Analytical Procedure

A critical structured narrative review was adopted because the research question crosses architectural design, affordable-housing studies, GenAI and computational design, BIM, building-performance simulation, POE, digital twins and AI governance. Narrative synthesis is suitable for heterogeneous conceptual, empirical, modelling, review and case-study evidence where effect sizes cannot be meaningfully pooled, while explicit search, selection, coding and appraisal procedures improve transparency (Grant & Booth, 2009; Green et al., 2006; Snyder, 2019).

Scopus and Google Scholar were used for principal literature discovery, supplemented by targeted searches of ScienceDirect, Taylor & Francis Online, MDPI-hosted journals and relevant institutional repositories. Institutional material from UN-Habitat, the International Energy Agency, the Intergovernmental Panel on Climate Change, the United Nations Environment Programme, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Organisation for Economic Co-operation and Development (OECD), and the International Organization for Standardization (ISO), together with Nigerian legal, regulatory and policy sources including the Architects (Registration, Etc.) Act, the National Building Code, the Nigeria Data Protection Act and the National Artificial Intelligence Strategy, were consulted separately for housing, climate, standards and governance context. Searches were completed on 30 July 2026. No rigid publication-year cutoff was applied: recent literature was prioritised for rapidly evolving GenAI and digital-twin topics, while earlier seminal studies were retained for Nigerian housing, computational space planning, BIM/lifecycle information and building optimisation.

Search concepts were organised into thematic blocks covering GenAI and learned generative models; generative and parametric architectural design; affordable housing and housing estates; spatial layout; BIM; building-performance simulation and optimisation; POE; digital twins; spatial efficiency; climate-responsive design; liveability; responsible AI; and Nigeria. Supplementary Table S1 provides an auditable operational search specification derived from these thematic blocks. Contemporaneous engine-specific query logs were not retained; accordingly, the supplementary expressions are reproducible search formulations rather than claimed verbatim historical strings.

Inclusion required substantial relevance to AI-assisted or computational architectural option generation, spatial layout, BIM coordination, performance simulation, digital-twin or POE feedback, affordability, liveability or responsible architectural practice. Promotional, duplicative, non-scholarly and weakly housing-related sources were excluded. Screening proceeded sequentially through duplicate identification, title review, abstract assessment and full-text relevance checking, followed by extraction into the analytical matrix. The review was purposive and iterative rather than protocol-registered and is therefore presented as a critical structured narrative synthesis rather than a PRISMA-compliant systematic review. Historical counts for records retrieved, duplicates removed and studies excluded at each screening stage were not retained; only the verified final corpus count is reported.

The bibliography contains 46 peer-reviewed scholarly publications used either for review methodology or substantive synthesis. Three—Grant and Booth (2009), Green et al. (2006), and Snyder (2019)—serve only the review-methodology rationale, leaving 43 peer-reviewed publications in the substantive analytical corpus. The remaining 15 reference-list entries comprise policy, standards, statutory, legal or institutional sources and are interpreted separately.

For each analytical study, the extraction matrix recorded author/year, country or context, housing/building scale, evidence type, computational method, data source where reported, variables, validation or evaluation procedure, principal contribution, limitations, evidential role and transferability to Nigerian affordable housing. Methodological appraisal considered study-design transparency, appropriateness of data, validation or evaluation procedures, reproducibility, relevance to architectural decision-making, contextual fit and transferability. Because the corpus combines empirical studies, reviews, computational demonstrations and conceptual work, a single numerical risk-of-bias score would create false comparability; the appraisal is therefore reported qualitatively and used to weight claims rather than to produce a pooled quality index.

Table 1: Review design and architectural analytical protocol

Review element	Operational focus in this paper
Review purpose	Synthesize how GenAI and related computational methods can support human-centred, architect-led but multidisciplinary affordable-housing design through option generation, information coordination, independent performance testing and lifecycle learning.
Evidence base	43 peer-reviewed analytical publications, supplemented by separately interpreted review-methodology, policy, standards, statutory, legal and governance sources.
Method taxonomy	GenAI/learned generative models; generative/parametric design; BIM/information management; conventional performance simulation/optimisation; POE; digital-twin functions.
Main themes	Option generation; unit/block/site design; spatial efficiency; climate response; BIM coordination; performance simulation; POE/digital-twin feedback; affordability; liveability; responsible AI.
Human-centred lens	Household needs and user diversity; resident participation; architectural judgement; accessibility; dignity; cultural fit; buildability; performance verification and learning in use.
Appraisal criteria	Methodological transparency; appropriateness of data; validation/evaluation; reproducibility; architectural relevance; contextual fit; Nigerian transferability.
Synthesis output	A six-stage architect-led lifecycle framework, implementation-readiness conditions, risk-governance controls, an illustrative Nigerian comparative pilot scenario and candidate indicators for empirical validation.
Search and screening record	Search completion: 30 July 2026. Principal discovery: Scopus and Google Scholar, with targeted publisher-platform and institutional searches. Screening sequence: duplicate identification, title review, abstract assessment and full-text relevance checking. Historical retrieval, duplicate-removal and exclusion counts were not retained; final analytical corpus n = 43.

Source: Authors' methodological synthesis informed by Grant and Booth (2009), Green et al. (2006), and Snyder (2019).

Note: The review does not estimate pooled effects and cannot establish that a GenAI, BIM or digital-twin application will improve Nigerian affordable housing without empirical validation.

Table 2: Characteristics and critical appraisal of the 43-study analytical corpus

Study	Context/evidence type	Method class	Principal contribution to this review	Critical limitation / Nigerian transferability
Abdul Mohit & Abbas Iyanda (2017).	Nigeria; low-income housing; empirical liveability study	Housing/ POE evidence	Shows that affordable-housing outcomes extend beyond unit provision to liveability and resident experience.	Direct Nigerian relevance, but not a GenAI study; informs evaluation criteria rather than AI effectiveness.

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Abioye et al. (2021).	International AEC; review	AI/AEC review	Maps AI applications and implementation opportunities/challenges across construction and the built environment.	Broad AEC evidence; limited direct evidence on affordable-housing architectural generation.
AlBalkhy et al. (2024).	Built environment; review	Digital-twin review	Clarifies digital-twin definitions, applications and implementation challenges.	International and heterogeneous; technical potential does not establish Nigerian housing feasibility.
Arvin & House (2002).	Architectural space planning; computational study	Knowledge-driven generative design	Demonstrates explicit objective/rule representation in computational space planning.	Predates contemporary GenAI; relevant to constraint logic, not evidence of learned generative AI.
Attia et al. (2013).	Building design; tool assessment	Performance optimisation	Identifies needs and gaps for integrating performance-optimisation tools into design workflows.	Net-zero/high-performance focus; requires adaptation to Nigerian affordable-housing conditions.
Batty et al. (2012).	Urban systems; conceptual/review	Urban digital systems	Supports estate-scale consideration of urban systems, data and service relationships.	Not housing-design or GenAI-specific; contextual rather than direct evidence.
Becerik-Gerber et al. (2012).	Facilities management; analytical study	BIM/lifecycle information	Defines BIM-enabled FM information needs and links design information to operation.	FM-focused and international; assumes information maturity not guaranteed in Nigerian estates.
Boje et al. (2020).	Construction lifecycle; conceptual/review	Digital twin	Develops semantic digital-twin directions and lifecycle information requirements.	Conceptual/technical; no evidence that digital twins are affordable or effective in Nigerian housing.
Brysch & Czischke (2022).	Collaborative housing; empirical/design-cost study	Affordable-housing design	Shows how design and building costs interact with affordability and spatial decisions.	Different tenure/context from Nigeria; useful for multi-criteria affordability rather than direct transfer.
Darko et al. (2020).	International AEC; scientometric study	AI/AEC mapping	Identifies research concentrations and trends in AI across AEC.	Bibliometric rather than performance evidence; weak direct support for housing-design effectiveness.
Deng et al. (2021).	AEC-FM; systematic review	BIM-to-digital-twin evolution	Distinguishes BIM and digital-twin evolution and operational information links.	International review; does not establish implementation

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				economics in Nigerian affordable housing.
Elwy & Hagishima (2024).	Sustainable building design; systematic review	AI surrogate modelling	Shows potential of surrogate models to accelerate building-design optimisation.	Requires validated training domains; limited direct evidence for Nigerian housing.
Evins (2013)	Sustainable building design; review	Computational optimisation	Establishes multi-objective optimisation and the need to make trade-offs explicit.	Not GenAI-specific; supports evaluation logic rather than generative model claims.
Ezennia & Hoskara (2019)	Housing affordability; qualitative methodological study	Affordability measurement	Shows that affordability is multidimensional and poorly captured by first cost alone.	General affordability evidence; does not establish digital-workflow benefits.
Gao & Pishdad-Bozorgi (2019).	Facilities O&M; review	BIM lifecycle information	Synthesises BIM use in operation/maintenance and information continuity.	High information-maturity assumptions; implementation burden may be significant in affordable housing.
Ghansah (2025)	Smart buildings/FM; systematic review	Digital twin	Reviews enablers, applications and challenges of digital twins in FM.	Smart-building emphasis and international evidence; Nigerian affordability remains untested.
Hakimi et al. (2024).	Facility management; bibliometric review	Digital twin	Maps digital-twin research for smart FM and operational use.	Bibliometric evidence; limited direct proof of housing outcomes or cost-effectiveness.
Hu et al. (2020).	Floor-plan generation; computational study	Learned layout generation	Graph2Plan demonstrates data-driven floor-plan generation conditioned by layout relationships.	Training/context transferability is uncertain; generated geometry requires independent architectural verification.
Ibem & Aduwo (2013).	Ogun State, Nigeria; empirical POE	Residential satisfaction	Provides direct Nigerian evidence that dwelling, services and neighbourhood conditions shape satisfaction.	Not computational; informs human-centred evaluation and local criteria.
Jang et al. (2025).	Architectural design; review	GenAI	Synthesises GenAI applications, data and evaluation methods in architectural design.	Rapidly evolving field; review evidence does not prove superiority in Nigerian affordable housing.

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Khajavi et al. (2019).	Buildings; conceptual/technical study	Digital twin	Clarifies digital-twin vision, boundaries and creation requirements for buildings.	Technical feasibility evidence; requires sustained data infrastructure and governance.
Li et al. (2024).	Smart/sustainable buildings; review	AI-BIM integration	Examines AI-BIM relationships and potential integration for sustainable building workflows.	Broad technology review; limited direct evidence on affordable-housing design outcomes.
Lu et al. (2020).	West Cambridge Campus; case study	Building/city digital twin	Demonstrates development of a digital twin at building and campus scale.	High-resource institutional context; transferability to affordable housing is limited.
Machairas et al. (2014).	Building design; review	Optimisation algorithms	Reviews algorithms for multi-objective building-design optimisation.	Not GenAI-specific and predominantly technical; requires human-centred criteria to avoid single-metric optimisation.
Makinde (2014)	Nigeria; housing delivery study	Housing context	Documents Nigerian housing need, demand and delivery constraints.	Contextual rather than computational; supports local feasibility assumptions.
Mulliner & Maliene (2015).	Housing affordability; professional perceptions	Multi-criteria affordability	Identifies multiple criteria contributing to sustainable housing affordability.	Non-Nigerian professional evidence; criteria require local validation.
Mulliner et al. (2013).	Housing affordability; MCDM study	Multi-criteria decision support	Demonstrates multi-criteria assessment of sustainable housing affordability.	Method transfer is possible, but weights and thresholds are context-dependent.
Nagy et al. (2017).	Architectural space planning; application	Generative design	Project Discover demonstrates constraint/objective-driven generative space planning.	Not contemporary GenAI; commercial/workplace context differs from affordable housing.
Nauata et al. (2020).	House layout generation; computational study	GAN-based layout generation	House-GAN demonstrates graph-constrained generative house-layout production.	Dataset dependence and architectural completeness require local validation and professional checking.
Nguyen et al. (2014).	Building performance; review	Simulation-based optimisation	Synthesises methods for simulation-based optimisation of building performance.	Not GenAI; model assumptions and calibration govern credibility.

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Nguyen & Adhikari (2023).	Building construction; review	BIM-digital twin integration	Reviews BIM's role in digital-twin integration during construction/lifecycle processes.	International review; data and interoperability requirements may exceed local capacity.
Ogundipe et al. (2024).	Lagos, Nigeria; empirical barrier study	Affordable-housing delivery	Identifies land, socioeconomic, material, technology and collaboration barriers to affordable housing.	Lagos-specific and not a GenAI evaluation; provides implementation-context evidence.
Opoku et al. (2021).	Construction; literature review	Digital twin	Synthesises digital-twin applications and challenges in construction.	Broad construction evidence; operational affordable-housing benefits remain untested.
Pan & Zhang (2021).	Construction engineering/management; critical review	AI/AEC	Reviews AI roles and future trends across construction engineering and management.	Management-heavy evidence; limited direct architectural generation evidence.
Pärn et al. (2017)	Facilities management; review	BIM/FM	Traces BIM trajectory into FM and lifecycle information use.	Assumes stable digital handover and information management; not GenAI-specific.
Pinti et al. (2022).	Public organisations; review	BIM/FM implementation	Reviews BIM implementation for facility management in public organisations.	Implementation challenges are informative, but not evidence of GenAI design performance.
Sacks et al. (2020).	Built environment; conceptual/review	BIM-AI-construction tech	Frames relationships among BIM, AI and construction technologies.	Broad conceptual scope; limited housing-specific empirical validation.
Shahat et al. (2021).	Urban digital twins; review	City digital twin	Reviews city-digital-twin potentials and research needs relevant to estate-scale context.	City-scale evidence; may be disproportionate for affordable-housing projects.
Ukoha & Beamish (1997)	Abuja, Nigeria; empirical POE	Residential satisfaction	Provides direct Nigerian resident-satisfaction evidence for public housing.	Older context and not computational; useful for resident-centred criteria.
Weil et al. (2023).	Urban digital twins; systematic review	Digital twin governance/implementation	Identifies interoperability, governance and sustainability challenges of urban digital twins.	Urban-scale international evidence; requires cautious transfer to housing-estate workflows.
White et al. (2021).	Smart-city case/application	Digital twin + citizen feedback	Shows how citizen feedback can be incorporated into a digital-twin environment.	City context and digital-access assumptions limit direct housing transferability.

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Yan et al. (2026).	Architectural spatial layouts; review	Generative design/GenAI-related	Reviews technical approaches to generative architectural layouts and evaluation.	Combines method classes; direct Nigerian cultural/regulatory validation remains absent.
Yigitcanlar et al. (2019).	Smart cities; systematic review	Human-centred/sustainability governance	Supports caution that digital intelligence does not inherently produce sustainable outcomes.	City-scale conceptual evidence; indirect to housing design but relevant to governance.

Note: The table distinguishes direct Nigerian housing evidence, computational/generative evidence, BIM/performance evidence, POE/resident evidence and digital-twin evidence. It does not imply equal evidential weight across studies. Older or non-GenAI methods are retained only where they inform constraint handling, evaluation, affordability, information continuity or lifecycle learning.

Evidence transfer was handled explicitly. Five analytical studies provide direct Nigerian housing evidence—Abdul Mohit and Abbas Iyanda (2017), Ibem and Aduwo (2013), Makinde (2014), Ogundipe et al. (2024), and Ukoha and Beamish (1997)—and inform local affordability, delivery constraints, liveability and resident-centred evaluation. Nigerian statutes and policy sources define professional, building and data-governance requirements. By contrast, the GenAI, learned-layout, BIM, simulation and digital-twin evidence is predominantly international. Those international studies are used to define methods, capability limits and testable indicators, not to infer that the same performance gains have already been demonstrated in Nigerian affordable housing.

Conceptual Foundations

For this review, GenAI refers specifically to learned generative systems used to produce or transform design-related content from training patterns and user-defined inputs, including applications to architectural briefing, spatial layouts and option exploration (Jang et al., 2025; Yan et al., 2026). Generative design is broader and more structured: architects or designers define goals, constraints and criteria while computational systems produce and compare alternatives (Nagy et al., 2017). Parametric design varies forms or relationships through explicit parameters. These categories overlap in workflows but should not be used as synonyms.

Affordable-housing architecture is also treated as a multi-criteria problem. Affordability is not equivalent to minimum first cost because habitability, accessibility, location, services, recurring costs, maintenance and cultural adequacy affect whether housing remains affordable and usable over time (Ezennia & Hoskara, 2019; Mulliner et al., 2013; UN-Habitat, 2026). Architectural affordability therefore includes the effects of floor area, form, circulation, envelope, materials, service complexity, adaptability and maintainability alongside purchase or construction cost.

Space efficiency is similarly distinguished from floor-area minimisation. Evidence from Nigerian housing and collaborative housing indicates that useful room proportions, circulation, furniture fit, storage, privacy, daylight, ventilation and adaptability matter to adequacy (Brysch & Czischke, 2022; Ibem & Aduwo, 2013; Ukoha & Beamish, 1997). Compactness becomes undesirable where reductions in area create overcrowding, weaken privacy or accessibility, or reduce environmental and functional quality.

Building-optimisation literature establishes design as a multi-objective problem in which geometric, environmental, energy and cost-related criteria may compete (Evins, 2013; Machairas et al., 2014; Nguyen et al., 2014). GenAI or computational optimisation is useful only where the criteria, objective functions and trade-offs used to generate or rank alternatives are transparent. A generated or ranked option should not be interpreted as an optimum architectural solution without professional, specialist and user-centred evaluation.

Human-centred practice retains accountable responsibility for problem definition, constraints, interpretation and approval with competent professionals while incorporating resident needs and specialist verification. GenAI may generate alternatives, BIM may coordinate information and operational systems may reveal performance, but

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none displaces competent human judgement or applicable professional responsibilities (Architects (Registration, Etc.) Act, 2004; ISO, 2023; OECD, 2024; UNESCO, 2021).

Affordable Housing Context in Nigeria

Global and Nigerian housing evidence links affordability with adequacy, resilience, infrastructure and environmental performance rather than unit cost alone (Ezennia & Hoskara, 2019; Makinde, 2014; United Nations Department of Economic and Social Affairs, n.d.; UN-Habitat, 2026). In Nigeria, urbanisation, high rents, overcrowding, peri-urban growth, limited mortgage access and uneven serviced-land provision constrain repeatable housing delivery (Ezennia & Hoskara, 2019; Makinde, 2014). Nigerian studies also identify land and tenure constraints, material inflation, limited finance, infrastructure deficits, procurement weaknesses and implementation capacity as barriers (Ogundipe et al., 2024). These conditions interact directly with architectural decisions on prototype dimensions, structural grids, service layouts, materials, climate response and phasing.

Nigerian POE evidence shows that housing outcomes extend beyond the number of units delivered to dwelling quality, infrastructure, services, location, maintenance and neighbourhood conditions (Abdul Mohit & Abbas Iyanda, 2017; Ibem & Aduwo, 2013; Ukoha & Beamish, 1997). Consequently, AI-generated housing alternatives intended for Nigerian application should be evaluated using locally verified household characteristics, spatial needs, climate files, material and construction information, infrastructure conditions, affordability assumptions and applicable statutory requirements before prototype replication.

Affordability assessment should also include the implementation burden of the digital workflow itself. One-time costs include software configuration, data preparation, model setup, training and specialist mobilisation; recurring costs can include licences or API/compute use, BIM information management, performance modelling, interoperability testing, cybersecurity, system maintenance and, where used, sensors, calibration and replacement. These costs should be compared with conventional-workflow costs and measurable project or lifecycle benefits using an agreed analysis period rather than assumed to be justified by technological novelty. ISO 15686-5 provides a structured basis for life-cycle cost comparison between alternatives (ISO, 2017). This is particularly important in affordable housing, where advanced digital functions may be disproportionate if institutional ownership, data maintenance or recurrent budgets are weak.

Housing performance extends beyond the individual dwelling to estate-level conditions such as location, access, shared services, infrastructure and neighbourhood quality (Batty et al., 2012; Mulliner et al., 2013; Mulliner & Maliene, 2015). The proposed framework translates these wider conditions into site, block, public-space and service-coordination decisions and treats resident evidence as a design input rather than only as a post-handover assessment.

Generative AI and Computational Design for Housing Options

Across AEC literature, AI applications span classification, prediction, generative modelling and decision support, while architectural option generation also draws on non-AI generative, rule-based, parametric and optimisation methods (Abioye et al., 2021; Darko et al., 2020; Pan & Zhang, 2021). These evidence classes are interpreted separately in this review. Contemporary GenAI is concentrated mainly in early and schematic design, where it can widen exploration but cannot independently establish dimensional adequacy, compliance, buildability or contextual fit (Jang et al., 2025).

Computational space planning includes knowledge-driven approaches based on explicit architectural rules and data-driven approaches that infer patterns from datasets (Arvin & House, 2002; Yan et al., 2026)—learned floor-plan systems such as Graph2Plan and House-GAN demonstrate that alternative spatial configurations can be generated from relational or graph-based inputs (Hu et al., 2020; Nauata et al., 2020), while generative-design applications such as Project Discover demonstrate explicit objective and constraint handling (Nagy et al., 2017). These studies are relevant to constraint management and option generation but should not all be described as GenAI.

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For affordable housing, the defensible workflow combines explicit architectural and regulatory constraints with data-driven or generative exploration. Room dimensions, functional adjacency, furniture fit, public-private gradients, accessibility, fire safety, structural logic, services, climate response, site conditions and budget limits should be specified or checked independently before design development. GenAI is therefore best treated as an exploratory layer that widens the alternative set; the architect and relevant specialists remain responsible for determining whether an alternative is coherent, compliant and buildable.

In repetitive housing, early design errors can be replicated across many units and blocks. Verification before repetition is therefore more important than visual novelty. Candidate GenAI applications include brief interpretation, precedent synthesis, unit-layout exploration and early alternative comparison. At the same time, conventional parametric/generative tools may remain preferable where objectives and rules need to be inspectable or deterministic. The appropriate method should be selected according to the design problem rather than the novelty of the technology.

BIM, Performance Simulation and Lifecycle Information

Shortlisted generated alternatives require translation into coordinated project information before they can be evaluated reliably. BIM can structure geometry, quantities, specifications, schedules and object information, supporting dimensional consistency, coordination and traceability across design and subsequent lifecycle use (Becerik-Gerber et al., 2012; Gao & Pishdad-Bozorgi, 2019; Li et al., 2024; Pärn et al., 2017). BIM itself does not validate design quality; credibility depends on model completeness, defined information requirements and review procedures. For pilots involving multiple platforms, information requirements, exchange responsibilities and version control should be defined using ISO 19650 principles. In contrast, open IFC exchange can be tested against ISO 16739-1 to reduce avoidable software lock-in and data loss (ISO, 2018, 2024). Where BIM information is retained into operation, handover, updating and responsibility arrangements should be defined under the same lifecycle information-management framework rather than assumed (ISO, 2018).

Building-performance simulation is treated separately from GenAI and BIM. Physics-based simulation can estimate daylight, thermal conditions, ventilation, energy demand and related outcomes, while simulation-based optimisation can compare alternatives under explicit objective functions (Attia et al., 2013; Evins, 2013; Nguyen et al., 2014). Validated AI surrogate models may reduce repeated simulation effort where they are trained on appropriate input-output data, tested independently and used within their validated parameter domain; they should supplement rather than replace physics-based evaluation where extrapolation is uncertain (Elwy & Hagishima, 2024).

POE is the baseline lifecycle-learning mechanism in the proposed framework. Structured resident surveys, maintenance records, defect histories, comfort measurements, accessibility observations and energy or service data can be linked back to design decisions without requiring a digital twin. BIM-enabled FM literature shows how retained component and maintenance information can support such continuity (Becerik-Gerber et al., 2012; Gao & Pishdad-Bozorgi, 2019; Pinti et al., 2022).

Digital twins represent a more data-intensive extension of lifecycle information. A digital twin is not simply a BIM model, sensor dataset, maintenance database or resident survey; it requires a maintained digital representation that is systematically linked to operational data and defined feedback functions (AlBalkhy et al., 2024; Boje et al., 2020; Deng et al., 2021; Khajavi et al., 2019). Digital-twin research indicates monitoring and maintenance potential, but the evidence is largely international and implementation-dependent. In Nigerian affordable housing, digital twins should therefore be framed as optional higher-maturity infrastructure rather than a mandatory end-state.

Spatial Efficiency, Adaptability and Housing Dignity

Space efficiency affects affordable-housing cost through floor area, envelope, services, finishes, circulation and land use, but affordability research also emphasises value-for-money and recurring burdens over time (Brysch & Czischke, 2022; Mulliner et al., 2013). GenAI may compare layouts and spatial relationships, but efficiency

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claims require evaluation against usability, privacy, daylight, ventilation, storage, accessibility and adaptability (Hu et al., 2020; Yan et al., 2026).

Housing dignity is treated as a non-reducible human-centred criterion reflected through adequate privacy, personal and family use, accessibility, cultural fit, freedom from avoidable overcrowding and the capacity to adapt the dwelling to everyday life. These qualities complement rather than disappear into numerical efficiency metrics. Nigerian housing evidence shows that residential satisfaction is shaped by dwelling quality, services and neighbourhood conditions, providing an empirical basis for keeping resident experience visible in the design criteria (Ibem & Aduwo, 2013; Ukoha & Beamish, 1997).

At block and estate scales, efficiency is affected by road structure, setbacks, open space, orientation, shade, pedestrian access, drainage, service routes and communal facilities. GenAI, BIM and performance tools contribute different functions: GenAI may generate alternatives, BIM may structure their geometry and information, and conventional simulation or validated surrogate models may estimate selected environmental outcomes. Their roles should not be collapsed into a single 'AI-enabled design' function.

The architect remains the integrator of unit, block and estate-scale quality, but this does not imply an architect-only workflow. Structural and services feasibility, cost, accessibility, infrastructure, environmental performance and resident evaluation may require specialist inputs. The architect's role is to integrate these requirements into coherent housing form and to document the basis for accepting, modifying or rejecting computational alternatives.

Human-Centred Architectural Governance

For this review, human-centred means more than retaining a human professional in the loop. It requires systematic representation of intended residents' needs, abilities, household practices and feedback within briefing, evaluation and lifecycle learning. Architect-led oversight remains necessary but is not a substitute for user participation. Human-centred governance therefore combines professional accountability with meaningful resident representation and specialist verification. At briefing, household profiles, target unit types, affordability limits, spatial needs, accessibility requirements, cultural practices, site conditions, climate data, material constraints, construction logic, infrastructure and performance targets should be made explicit. Where resident engagement is practicable, intended users or representative households should inform priorities before options are generated. This reduces the risk that computational objectives encode only institutional or designer assumptions.

At option evaluation, generated unit, block and estate alternatives should be assessed against functional relationships, room proportions, furniture fit, privacy gradients, circulation, orientation, shade, ventilation, daylight, open space, drainage interfaces, access, services, buildability and affordability. Resident/user evaluation can add evidence on everyday practices, cultural fit, privacy and adaptability that is difficult to encode numerically.

After occupation, POE should return comfort, defects, maintenance, accessibility, adaptation and resident satisfaction to future briefs and prototypes. Where advanced operational systems are justified, digital-twin functions may automate or deepen selected feedback. Across all stages, responsible-AI principles require transparent objectives, documented limitations, traceable review and accountable human approval (ISO, 2023; OECD, 2024; UNESCO, 2021).

Table 3: Architect-led digital and AI-assisted functions across the affordable-housing design lifecycle

Method class	Digital function	Architectural responsibility	Evidence / metric	Decision output
GenAI / learned generative method.	Unit-layout option generation	Define household brief, adjacencies, dimensions,	Net-to-gross ratio; room usability; circulation; furniture	Shortlisted dwelling concepts

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		privacy, accessibility and ventilation constraints.	fit; privacy; adaptability.	requiring independent verification.
Generative/parametric optimisation	Block and site alternatives	Coordinate orientation, spacing, access, shade, landscape, drainage interfaces, communal space and service relationships.	Site utilisation; solar exposure; airflow potential; walking access; open-space quality; infrastructure relationships.	Alternative block/estate configurations for professional and resident review.
BIM/information management	Coordination and traceability	Translate shortlisted options into coordinated objects, quantities, specifications, schedules and details.	Dimensional consistency; clash resolution; quantity traceability; information completeness.	Auditable design and construction information.
Conventional performance simulation	Environmental/performance testing	Interpret daylight, thermal, ventilation, energy, material and related results and revise design.	Daylight; comfort; ventilation; energy; envelope/material indicators; sensitivity where relevant.	Performance-filtered architectural alternative.
POE	Baseline lifecycle feedback	Relate defects, comfort, maintenance, accessibility, adaptation and resident feedback to prior decisions.	Defect recurrence; comfort; maintenance events; resident satisfaction; adaptation observations.	Revised briefs, details and future prototypes.
Optional digital-twin function	Operationally linked feedback	Use maintained digital representation and operational data only where a defined use case and sustained data process exist.	Operational trends; sensor-linked performance; work orders; asset condition; user/service evidence.	Higher-maturity continuous or periodic lifecycle feedback.

Source: Authors' synthesis based on generative-design evidence (Hu et al., 2020; Jang et al., 2025; Nagy et al., 2017; Nauata et al., 2020; Yan et al., 2026), BIM/lifecycle literature (Becerik-Gerber et al., 2012; Gao & Pishdad-Bozorgi, 2019; Li et al., 2024; Pinti et al., 2022), performance-optimisation evidence (Evins, 2013; Nguyen et al., 2014), POE and resident evidence (Abdul Mohit & Abbas Iyanda, 2017; Ibem & Aduwo, 2013; Ukoha & Beamish, 1997), and digital-twin evidence (Boje et al., 2020; Deng et al., 2021; White et al., 2021).

Note: The functions are proposed decision-support roles derived from the synthesis and are not a validated Nigerian GenAI-housing assessment protocol.

Ethical, Regulatory and Technical Risks

GenAI in housing raises ethical, regulatory and technical risks because architectural decisions affect safety, privacy, affordability, dignity, wellbeing and long-term performance. Responsible-AI guidance emphasises transparency, fairness, accountability and human oversight, while ISO/IEC 42001 provides an organisational framework for managing AI-related risks and opportunities (ISO, 2023; OECD, 2024; UNESCO, 2021). In Nigeria, professional architectural practice remains subject to the Architects (Registration, Etc.) Act; generated proposals require independent checks against applicable building requirements, including the National Building Code where relevant; and any processing of personal data must comply with the Nigeria Data Protection Act, 2023. The National Artificial Intelligence Strategy provides additional national policy direction for responsible

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and inclusive AI adoption (Architects (Registration, Etc.) Act, 2004; Federal Ministry of Communications, Innovation and Digital Economy, 2025; Federal Republic of Nigeria, 2006; Nigeria Data Protection Act, 2023). These requirements are verification gates, not parameters that should be assumed to have been satisfied by a generated output.

Data representativeness is a major transferability risk where generative models or precedents inadequately reflect Nigerian household structures, abilities, cultural practices, climates, materials, construction systems or regulatory conditions. Where training data are inaccessible—as with many proprietary systems—the limitation itself should be documented and outputs subjected to stronger independent local validation. Curated local climate files, verified precedents, material libraries, code rules, household evidence and POE datasets can constrain generation and strengthen evaluation.

Transparent GenAI-assisted comparison requires explicit objectives and documented assumptions. Density, compactness or first-cost objectives may conflict with daylight, privacy, adaptability, maintainability or liveability. Model/version opacity also creates reproducibility problems: changes to proprietary systems, undocumented prompt settings or inaccessible training information may prevent later recreation of an option. Project records should therefore identify the model/provider, version or date, relevant prompts/parameters, input files and material changes to the design.

Visual or geometric plausibility does not establish compliance. GenAI-generated layouts may omit or mishandle dimensional, fire-safety, accessibility, structural, sanitary, setback, daylight, drainage or other approval requirements. Generated outputs should therefore be treated as unverified proposals until the relevant architect-led, specialist and statutory checks are completed. Human oversight is a control, but it is credible only where the review itself is documented.

Table 4: Architectural risk-governance matrix for GenAI-assisted affordable housing

Risk	Architectural consequence	Human-centred control	Verification evidence
Data bias/weak local relevance	Cultural mismatch, poor climate response, unrealistic dimensions or inappropriate estate form.	Use locally relevant household, climate, material and precedent evidence; document data gaps and transferability limits; strengthen resident review.	Documented data sources, limitations and local validation record.
Hidden optimisation trade-offs	Density, compactness or cost may undermine daylight, privacy, adaptability, dignity or liveability.	State objectives, weights and constraints; compare alternatives across multiple criteria; record why an option was selected.	Option-comparison matrix and decision rationale.
Code, safety or accessibility failure	Generated layouts may be unsafe, inaccessible or unapprovable.	Apply independent dimensional, fire-safety, accessibility and statutory checks before design development.	Architect-led compliance record plus relevant specialist/statutory review.
Unrealistic buildability or affordability	Visually plausible schemes may require impractical spans, services, materials or recurring costs.	Coordinate structure/services; check quantities, material intensity, maintainability, lifecycle cost and digital-workflow burden.	BIM schedules, quantity/cost checks and constructability review.
Misleading visual plausibility	Photorealistic outputs may conceal unresolved plans, sections, interfaces	Evaluate coordinated drawings, dimensions, sections, details	Coordinated documentation and performance evidence.

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	or performance assumptions.	and measurable performance rather than images alone.	
Automation, authorship and data risk	Overreliance may weaken design judgement, confidentiality, IP control or traceability.	Maintain human approval, source checks, access controls, provenance records and a design audit trail.	Record review decisions and controlled project information.
Model/version opacity and reproducibility	Updates to proprietary models or undocumented settings may make results difficult to reproduce or audit.	Record model/provider, version/date, prompts/parameters, input files and material design changes.	Reproducible project audit record and versioned design decision log.

Source: Authors' synthesis based on responsible-AI guidance and Nigerian AI policy (Federal Ministry of Communications, Innovation and Digital Economy, 2025; ISO, 2023; OECD, 2024; UNESCO, 2021), Nigerian professional, building and data-protection requirements (Architects (Registration, Etc.) Act, 2004; Federal Republic of Nigeria, 2006; Nigeria (Data Protection Act, 2023), Nigerian housing evidence (Ezennia & Hoskara, 2019; Makinde, 2014; Ogundipe et al., 2024), and BIM/digital-twin literature (Becerik-Gerber et al., 2012; Boje et al., 2020; Deng et al., 2021).

Evidence Consensus, Tensions and Gaps

The reviewed literature supports a potential lifecycle integration of complementary technologies rather than demonstrating a universally established sequence. GenAI can widen early option exploration, BIM can provide coordinated and traceable information, conventional simulation can test selected performance criteria, POE can evaluate performance in use, and digital twins may extend operational feedback where data maturity and organisational capacity support them. Reliability across these stages depends on explicit constraints, information quality, validation, interoperability and accountable interpretation.

A central tension concerns what can be encoded and measured. Density, net-to-gross efficiency, quantities, daylight and some environmental outputs are comparatively amenable to computational assessment. In contrast, dignity, privacy, cultural fit, household adaptation, informal livelihood needs and neighbourhood identity require contextual interpretation. Multi-objective methods can expose trade-offs but cannot determine their social acceptability. Resident evidence and professional judgement therefore remain essential.

A second tension concerns sophistication versus proportionality. More advanced digital infrastructure can improve information continuity and operational visibility but also introduces software, training, interoperability, sensor, cybersecurity, maintenance and data-governance burdens. For affordable housing, these costs matter. Structured POE and BIM-linked maintenance information may provide adequate lifecycle learning in many projects; sensor-rich digital-twin functionality should be adopted selectively where a defined use case and expected lifecycle benefit justify the additional burden.

The largest evidence gap is Nigerian empirical validation. Direct studies comparing conventional and GenAI-assisted architectural workflows on the same affordable-housing brief are absent from the corpus, and operational digital-twin evidence in completed Nigerian affordable-housing estates is limited. Consequently, the framework presented below is a testable synthesis rather than an established protocol.

Human-Centred Architect-Led Lifecycle Framework

The proposed framework comprises six stages that distinguish option generation from site analysis, information coordination, verification and lifecycle learning. Stage 1 is a verified housing and affordability brief covering household profiles, target unit mix, spatial needs, affordability limits, cultural practices, accessibility, statutory controls and performance requirements. Resident or representative household evidence should inform this stage where practicable.

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Stage 2 is site, climate and context analysis. Current site conditions, climate and weather data, access, infrastructure, materials, construction practices, environmental risks and local constraints are translated into explicit design requirements. This stage occurs before GenAI generation so that computational exploration is conditioned by the actual context rather than corrected only after images or layouts are produced.

Stage 3 is constrained GenAI option generation. Unit, block and estate alternatives are generated within defined dimensional, adjacency, orientation, ventilation, service, accessibility and budget constraints. The purpose is to widen exploration, not to select a final design. The architect compares coherence, usability, climate response, affordability and contextual fit before shortlisting options.

Stage 4 is BIM coordination and performance testing. Shortlisted alternatives are reconstructed or developed as coordinated information, quantities, schedules and specifications and are assessed through conventional performance methods where relevant. Simulation and cost/quantity analysis expose trade-offs and provide evidence for revision; they do not transfer professional responsibility to the software.

Stage 5 is architectural, specialist and resident validation plus construction information. Dimensional and statutory checks, structural and services feasibility, affordability/buildability review, and resident/user evaluation where practicable are integrated into the design decision. A documented rationale and coordinated construction information accompany the selected option.

Stage 6 is occupation, POE and optional digital-twin feedback. Comfort, defects, energy, maintenance, accessibility, resident adaptation and service performance are reviewed against the original brief and predicted outcomes. These findings update local evidence, future briefs, constraints and prototypes. Digital-twin functions may deepen or automate selected monitoring only where sustained operational data, governance and lifecycle value justify them.

The framework is deliberately tiered. Basic lifecycle learning can be achieved through structured POE, maintenance records and BIM-linked project information; sensor-rich digital-twin functions represent a higher-maturity option to be adopted selectively where data quality, institutional capacity, governance and lifecycle benefit justify their additional cost.

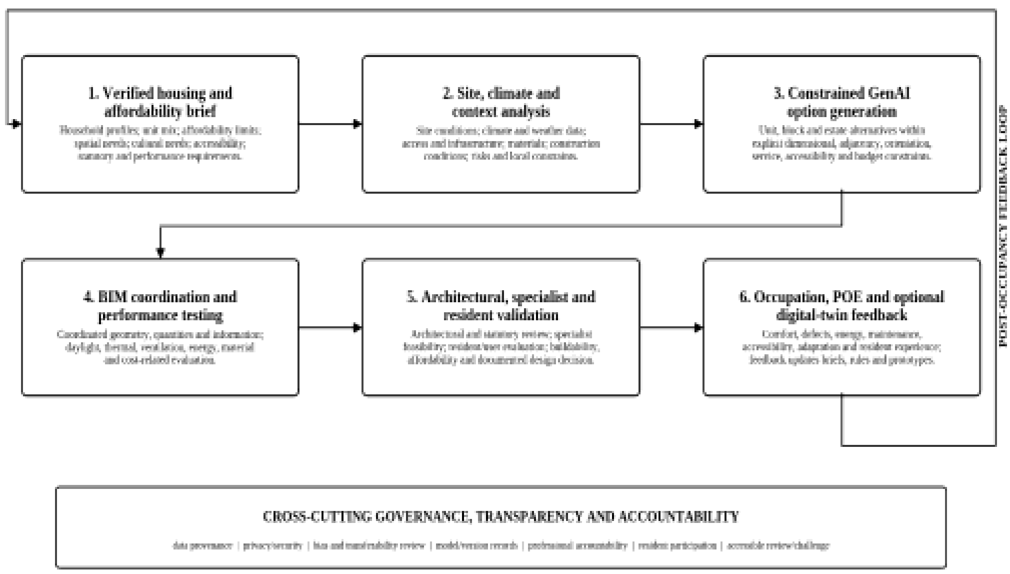

Figure 1: Proposed human-centred, architect-led lifecycle framework integrating constrained GenAI, BIM, performance evaluation and post-occupancy learning for affordable housing in Nigeria.

Source: Authors' conceptual synthesis based on affordable-housing and Nigerian resident evidence (Abdul Mohit & Abbas Iyanda, 2017; Ezennia & Hoskara, 2019; Ibem & Aduwo, 2013; Makinde, 2014; Ukoha & Beamish, 1997), generative-design evidence (Hu et al., 2020; Jang et al., 2025; Nagy et al., 2017; Nauata et al., 2020; Yan et al., 2026), BIM/performance literature (Becerik-Gerber et al., 2012; Gao & Pishdad-Bozorgi, 2019; Nguyen et al., 2014), digital-twin evidence (Boje et al., 2020; Deng et al., 2021; White et al., 2021), and governance/accountability guidance (Architects (Registration, Etc.) Act, 2004; Federal Ministry of Communications, Innovation and Digital Economy, 2025; ISO, 2023; Nigeria Data Protection Act, 2023; OECD, 2024; UNESCO, 2021).

Nigerian Implementation Readiness and Illustrative Pilot Scenario

Based on the synthesis, practical deployment can be assessed through five proposed readiness gates before Stage 3 option generation: data readiness, capability readiness, interoperability readiness, regulatory readiness and economic readiness. Data readiness requires a verified housing brief, household and accessibility requirements, site survey, climate/weather inputs, material and construction assumptions, infrastructure constraints, current cost data and applicable regulatory criteria. Capability readiness requires a registered architect as design integrator plus BIM/information-management, building-performance, cost/quantity, relevant engineering, resident/user-evaluation and data-governance competence as needed. Interoperability readiness requires defined information requirements, exchange responsibilities and open-format tests. Regulatory readiness requires documented professional, building and data-protection checks. Economic readiness requires separate reporting of licences/subscriptions, API/compute use, data preparation, BIM coordination, simulation, training, specialist verification, interoperability, cybersecurity and any sensor installation or maintenance, with alternatives compared over an agreed life-cycle costing period (AlBalkhy et al., 2024; ISO, 2017, 2018, 2023, 2024; Jang et al., 2025; Ogundipe et al., 2024; Pinti et al., 2022).

A concrete illustrative pilot could examine a publicly supported estate in Ado-Ekiti with approximately 120 dwellings and repeatable two- and three-bedroom unit types. The 120-dwelling scale is a worked scenario rather than a recommended statistical sample size; an empirical study should determine its sample and allocation from the actual estate population, intended comparisons and statistical design. A conventional arm and a GenAI-assisted arm would receive the same verified brief, site boundary, weather file, household profiles, material assumptions, price date, statutory criteria and performance targets. The conventional arm would use the normal architect-led workflow with BIM and performance testing; the experimental arm would add constrained GenAI only at Stage 3. Both arms would then undergo identical BIM coordination, simulation, quantity/cost review, specialist compliance checks and resident evaluation. Table 5 provides common indicators for design time, spatial adequacy, accessibility, environmental performance, buildability, cost, verification effort, resident acceptability and governance. If a scheme proceeds to construction, Stage 6 should add structured POE covering at least one full climatic year where feasible. Sensor-rich or digital-twin functions should remain optional and should proceed only when project-specific data, responsible roles, interoperability, regulatory compliance and recurrent funding are adequate; no universal monetary adoption threshold is proposed.

Implications For Practice and Policy

For housing-delivery institutions, the synthesis supports an architectural digital brief that specifies minimum data requirements, resident/user evidence, BIM-compatible deliverables, information-exchange rules, performance targets, compliance responsibilities, POE requirements and AI-governance provisions. Procurement documentation should clarify authorship, information ownership, common-data-environment responsibilities, interoperability and export requirements, cybersecurity, bias and transferability review, audit trails, specialist responsibilities and registered professional accountability (ISO, 2018, 2023, 2024; OECD, 2024; Pärn et al., 2017; UNESCO, 2021).

For architectural practice, computational option studies should be evaluated through coordinated plans, sections, dimensions, quantities and performance evidence rather than visual output alone. The appropriate method class should be explicit: GenAI for learned generation, generative/parametric methods for rule- or parameter-driven exploration, BIM for information coordination, and simulation for performance testing. Project teams should document important assumptions and retain the reasons for accepting, modifying or rejecting generated options.

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At estate scale, architectural evaluation should compare density, block spacing, orientation, access, shade, landscape, drainage interfaces, communal space, walking connections, service routes and infrastructure relationships rather than unit yield alone. Resident evaluation should be incorporated before replication where feasible, especially where proposed spatial efficiencies affect privacy, accessibility, cultural practices or adaptability.

Professional education and continuing development should address not only GenAI operation but also constraint definition, BIM information management, open information exchange, performance simulation, POE, affordability and lifecycle costing, model/version documentation, data quality, privacy and ethical review. The objective is not tool proficiency alone but the capacity to interrogate outputs, understand uncertainty, work across specialist interfaces and document accountable decisions. Project capability should therefore be assessed before procurement rather than inferred from access to software.

Limitations And Research Agenda

This review is limited by its critical structured narrative rather than systematic or meta-analytic design, purposive and iterative source selection, heterogeneous evidence base and absence of pooled effect estimation. Historical search and screening counts were not retained, which limits complete replication even though the search date, source types, search blocks, inclusion/exclusion logic and final analytical corpus are reported. Evidence directly examining GenAI-assisted affordable-housing architecture in Nigeria is sparse, and much of the computational evidence derives from non-Nigerian contexts or from generative-design approaches that are not equivalent to contemporary GenAI. Operational digital-twin evidence in Nigerian affordable housing is also limited. The proposed framework, readiness conditions and pilot protocol therefore remain testable propositions and should not be interpreted as demonstrated improvements in performance, affordability or transferability. Rapid model evolution, proprietary system opacity and changing software capabilities further limit reproducibility and may shorten the relevance of tool-specific conclusions. The framework therefore emphasises method classes, information quality, governance and decision principles rather than named commercial platforms. The reviewed evidence cannot establish that GenAI-generated alternatives are superior to conventional architectural workflows.

Future research should undertake comparative Nigerian housing pilots in which conventional and GenAI-assisted workflows address the same verified brief and are evaluated prospectively using predefined measures of design time, spatial quality, accessibility, compliance, environmental performance, constructability, quantities and cost, resident acceptability, professional workload, data completeness and interoperability. Random allocation of independent design teams is preferable where feasible; otherwise, matched teams should use the same input package, programme and evaluation criteria. Subsequent POE should test whether predicted advantages persist after occupation and should distinguish design effects from management, location and service-quality influences. Comparative pilots should distinguish the incremental contribution of GenAI option generation, BIM coordination, performance simulation and POE/digital-twin feedback rather than treating the digital workflow as one intervention. Costs for each layer should be recorded separately so that any improvement in design quality, decision speed or lifecycle performance can be judged against the additional professional, software, data, interoperability and maintenance burden. Causal claims should be reserved for outcomes supported by an appropriate comparator and transparent measurement protocol.

Table 5: Candidate indicators for empirical validation of the lifecycle framework

Domain	Indicator	Operational definition/unit	Framework stage	Data source	Comparison/ baseline	Interpretation/ limitation
Design efficiency	Design time	Professional hours from verified brief to comparable shortlisted option.	1–5	Time logs/project records	Conventional vs GenAI-assisted workflow	Faster output is beneficial only if quality and verification effort are maintained.

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Spatial quality	Net-to-gross efficiency	Net usable internal area / gross floor area (%), reported with room adequacy checks.	3–5	BIM/model measurements	Same brief and unit type	Higher efficiency can conceal undersized or unusable rooms.
Spatial quality	Functional adequacy	Compliance with room dimensions, furniture fit, circulation, privacy and storage criteria.	3–5	Architectural review matrix	Predefined brief / conventional design	Requires qualitative as well as dimensional judgement.
Accessibility	Inclusive-use compliance	Proportion of applicable accessibility requirements satisfied and unresolved deviations.	3–5	Compliance audit	Applicable statutory/design criteria	Formal compliance may not capture all user experience.
Environmental performance	Daylight/ thermal/ ventilation indicators	Project-specific simulation or measured metrics under stated assumptions.	4, 6	Simulation + POE monitoring	Same weather/occupancy assumptions; later measured outcomes	Model outputs require transparent inputs; POE provides stronger evidence.
Buildability	Constructability issues	Number/severity of coordination, span, service or detailing issues before construction.	4–5	BIM coordination/specialist review	Conventional vs GenAI-assisted	Issue counts depend on review intensity.
Capital affordability	Estimated construction cost	Comparable cost per dwelling and/or m² using stated quantity and pricing basis.	4–5	BIM quantities/cost plan	Same specification and price date	Cost estimate accuracy depends on market volatility and scope.
Lifecycle affordability	Expected recurrent burden	Maintenance, energy/service and adaptation implications expressed in project-specific cost terms where data allow.	4–6	Cost model / POE / maintenance records	Defined baseline design	Long-term estimates remain uncertain until observed.

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Professional workload	Verification burden	Architect/specialist hours spent correcting, validating and documenting generated options.	3–5	Time logs/review records	Conventional design effort	GenAI may shift rather than reduce workload.
Resident acceptance	Option acceptability	Resident or representative-household rating of privacy, usability, cultural fit, accessibility and adaptability.	1, 5	Structured user evaluation	Conventional and GenAI-assisted options	Sampling and representation must be reported.
POE outcome	Resident satisfaction/adaptation	Post-occupancy satisfaction and documented adaptation/alteration patterns.	6	POE survey/ observation	Predicted design criteria; comparator estate where possible	Affected by management, location and service quality beyond design.
POE outcome	Defect/maintenance recurrence	Frequency and type of recurrent defects or maintenance events linked to design decisions.	6	Maintenance/ work-order records	Prior prototype/comparator	Requires consistent recording and causal caution.
Digital workflow cost	Implementation burden	Software, training, modelling, data, interoperability, sensor, cybersecurity and maintenance cost.	All	Project accounts/ procurement records	Conventional information workflow	Should be compared against measurable decision or lifecycle benefit.
Governance	Traceability compliance	Proportion of consequential AI-assisted decisions with recorded model/version, inputs, assumptions, reviewer and rationale.	3–5	Design audit trail	Proposed project target: 100% documentation of predefined consequential AI-assisted decisions.	Measures documentation, not substantive design quality.

Source: Authors' synthesis based on affordable-housing and affordability evidence (Brysch & Czischke, 2022; Ezennia & Hoskara, 2019; Mulliner et al., 2013), Nigerian resident/POE evidence (Abdul Mohit & Abbas

Iyanda, 2017; Ibem & Aduwo, 2013; Ukoha & Beamish, 1997), building-performance and optimisation literature (Attia et al., 2013; Evins, 2013; Nguyen et al., 2014), BIM/lifecycle and interoperability guidance (Becerik-Gerber et al., 2012; Gao & Pishdad-Bozorgi, 2019; ISO, 2017, 2018, 2024; Pinti et al., 2022), Nigerian professional and governance requirements (Architects (Registration, Etc.) Act, 2004; Federal Ministry of Communications, Innovation and Digital Economy, 2025; Federal Republic of Nigeria, 2006; Nigeria Data Protection Act, 2023), and responsible-AI governance (ISO, 2023; OECD, 2024; UNESCO, 2021).

Note: Indicators should be pre-specified for each pilot, reported with the relevant baseline and interpreted together. No single metric establishes design superiority or affordability.

CONCLUSION

The reviewed evidence supports the cautious use of GenAI for widening early architectural exploration. However, it does not establish that GenAI-generated alternatives are superior to conventional architectural workflows in Nigerian affordable housing. Any performance advantage remains an empirical question requiring controlled local evaluation. Generated outputs should therefore be treated as unverified proposals until they have passed architectural, statutory, performance, buildability and relevant specialist checks.

A proposed lifecycle sequence links constrained GenAI exploration with BIM-based information coordination, independent performance evaluation and POE. Digital-twin functionality may extend lifecycle feedback where its technical, organisational and economic requirements are justified. This distinction is important because meaningful design learning does not require every affordable-housing project to adopt a sensor-rich digital twin.

The framework is particularly relevant to repetitive housing because design decisions are replicated across multiple units and blocks; both beneficial and adverse effects can therefore accumulate. Spatial efficiency must be evaluated alongside dignity, privacy, adaptability, accessibility, climate response, cultural fit, buildability and cost-in-use, while intended residents should be visible before occupation as well as through post-occupancy feedback.

The article contributes a proposed human-centred, architect-led but multidisciplinary lifecycle framework for Nigerian affordable housing together with explicit implementation-readiness conditions, an illustrative comparative pilot protocol and measurable validation indicators. GenAI is positioned as constrained option generation, BIM as information coordination, conventional analysis as performance verification, POE as the baseline learning mechanism and digital twins as an optional higher-maturity feedback layer. The framework should be tested against defined conventional-design baselines using the same project inputs and transparent indicators of spatial quality, environmental performance, compliance, construction information, affordability, professional effort, data readiness, interoperability, resident experience and post-occupancy outcomes. Until such comparative Nigerian evidence exists, the framework supports disciplined experimentation rather than a claim of GenAI superiority.

Data Availability: No new primary dataset was generated. The review is based on the published literature, standards, statutes and institutional documents cited in the article; study-level characteristics are reported in Table 2, and the search specification is provided in Supplementary Table S1.

Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: Not applicable. The study used published literature and publicly available institutional, statutory and standards documents and involved no human or animal participants.

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SUPPLEMENTARY MATERIAL

Supplementary Table S1: Reproducible operational search specification

Search block	Illustrative reproducible expression	Primary source(s)	Evidence sought	Important note
GenAI + architectural design	("generative AI" OR "generative artificial intelligence" OR "learned generative model") AND (architectur* OR "floor plan" OR "spatial layout")	Scopus; Google Scholar; publisher platforms	GenAI-specific architectural option generation, layout generation, evaluation and constraints.	Reproducible formulation; verbatim historical query log unavailable.
Generative/parametric design	("generative design" OR "parametric design" OR "computational space planning") AND (architectur* OR housing OR building)	Scopus; Google Scholar	Rule/constraint-driven generation and optimisation relevant to architectural alternatives.	Analysed separately from GenAI.
Affordable housing + Nigeria	("affordable housing" OR "public housing" OR "low-income housing") AND (Nigeria OR Nigerian) AND (design OR architecture OR liveability OR satisfaction OR affordability)	Scopus; Google Scholar; institutional repositories	Nigerian affordability, delivery barriers, residential satisfaction and local design criteria.	Direct Nigerian evidence receives greater transferability weight.
BIM + lifecycle	("Building Information Modelling" OR BIM) AND (architecture OR housing OR "facilities management" OR	Scopus; Google Scholar; publisher platforms	Information coordination, quantities, handover and lifecycle continuity.	BIM treated as information management, not AI.

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	lifecycle OR maintenance)			
Performance simulation/optimisation	("building performance" OR simulation OR optimisation OR optimization) AND (architectur* OR housing OR building) AND (daylight OR thermal OR energy OR ventilation)	Scopus; Google Scholar	Physics-based performance testing and multi-objective optimisation.	Physics-based simulation separated from AI surrogate models.
POE + resident evidence	("post-occupancy evaluation" OR POE OR "resident satisfaction" OR "occupant feedback") AND (housing OR residential OR building)	Scopus; Google Scholar	Resident experience, defects, adaptation, comfort and feedback for lifecycle learning.	POE treated as the baseline feedback mechanism.
Digital twin	("digital twin" OR "digital twins") AND (building OR housing OR construction OR "facility management")	Scopus; Google Scholar; publisher platforms	Definitions, BIM links, monitoring, maintenance, interoperability and governance.	Digital twin not equated with BIM, sensors or POE alone.
Responsible AI/governance	("responsible AI" OR "AI governance" OR "AI ethics" OR "human-centred AI") AND (architecture OR construction OR built environment OR design)	Scopus; Google Scholar; ISO; OECD; UNESCO; Nigerian legal/regulatory and policy sources including the Architects (Registration, Etc.) Act, Nigeria Data Protection Act and National Artificial Intelligence Strategy	Transparency, bias, accountability, human oversight, risk management and data governance.	Institutional guidance interpreted separately from the analytical corpus.

Searches were completed on 30 July 2026. Historical retrieval and duplicate-removal counts and archived engine-specific strings were not retained. The expressions above operationalise the reported search blocks for rerunning and future updating. The analytical corpus contains 43 peer-reviewed publications; methodology and authoritative policy, standards, statutory and governance sources are excluded from that count.