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Assessing the Level of Development (LoD) and Building Energy Efficiency Code (BEEC) 2022 Compliance in the Documentation of Building Envelope Systems in Modern Nigerian Architecture

Okor Michael Uduma

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Department of Architecture, Abia State University, Uturu, Nigeria. Email: michael.okor@abiastateuniversity.edu.ng

ABSTRACT

The building envelope critically influences energy performance, thermal comfort, durability, and aesthetics. Although contemporary envelope systems are increasingly used in Nigerian architecture, their documentation in working drawings often remains inadequate for compliance with the Building Energy Efficiency Code (BEEC) 2022. This study assessed the Level of Development (LOD) and BEEC 2022 compliance of envelope documentation in modern Nigerian architecture. Guided by Systems, Performance, and Information Modelling theories, a pragmatic convergent parallel mixed-methods design was employed. Sixty working-drawing sets (30 academic and 30 professional) produced between 2020 and 2025 were audited using a validated 25-item BEEC-LOD checklist. In addition, 132 questionnaires were completed by ARCON-registered principals and architecture lecturers. Results showed predominant use of conventional systems: 86.7% of sets specified 225 mm hollow sandcrete block walls, 80% specified uninsulated aluminium roofing, and 76.7% specified single clear glazing. Mean window-to-wall ratio was 42.6%, exceeding the BEEC limit of 30%. Documentation quality was low: 76.7% of sets were classified as LOD 200, 20% as LOD 300, and only 3.3% as LOD 350. Overall BEEC compliance stood at 14.22%, with particularly low scores for roof (11.2%) and general/LOD indicators (6.8%). Calculated U-values, projection factors, and formal compliance tables were almost entirely absent. The highest-ranked barriers were the absence of locally calibrated BIM libraries, limited lecturer capacity in BIM and BEEC, curriculum constraints, and weak regulatory enforcement. In response, a three-layer Sustainable Envelope Integration Framework (SEIF) is proposed to support the transition from predominantly LOD 200 documentation toward LOD 350 practice consistent with BEEC 2022 requirements.

Keywords: Building Envelope, Level of Development (LOD), Building Energy Efficiency Code (BEEC) 2022, Working Drawings, BIM, Thermal Performance, Documentation Compliance, SEIF.

INTRODUCTION

The building envelope separates the internal environment of a building from external climatic conditions and comprises external walls, roofs, floors, windows, doors, shading devices, and their interfaces. Its design influences thermal comfort, moisture control, durability, and energy consumption (Aksamija, 2013; ASHRAE, 2022). In Nigeria's tropical climate, adequate envelope design and documentation are important for controlling heat gain and supporting energy-efficient buildings.

Historically, envelope documentation evolved from conventional architectural drawings to performance-oriented documentation following the 1973 global energy crisis and the introduction of ASHRAE Standard 90-75 in 1975. More recently, Building Information Modelling (BIM) has facilitated the integration of geometry, material information, specifications, and performance data into coordinated building documentation. ISO 19650-1:2018 provides a framework for managing building information, while BIMForum (2023) defines Levels of Development (LOD) for model elements and their coordination. LOD 300 generally represents elements with defined geometry, while LOD 350 incorporates interfaces and additional information required for coordination.

However, detailed geometry alone does not establish compliance with energy-efficiency requirements; appropriate material and performance information must also be available.

Contemporary Nigerian architecture incorporates envelope systems such as curtain walls, aluminium screens, insulated roofs, green roofs, and alternative walling materials. Examples include curtain-wall systems in Eko Atlantic City, Lagos; aluminium screens at the Nigerian National Petroleum Corporation Towers, Abuja; ventilated roofs at the NAF Conference Centre, Abuja; green roofs in Banana Island; and compressed earth block construction at the Centre for Black Culture and International Understanding, Oyo (Adedokun et al., 2022). The effectiveness of these systems depends on appropriate specification, detailing, and coordination in architectural working drawings.

Saka et al. (2024) reportedly found that 86% of UK firms, 34% of South African firms, and 7% of Nigerian firms documented building envelopes at LOD 350 with automated U-value tagging. In Nigeria, drawings may identify walls simply as “225mm sandcrete block wall plastered and painted,” without specifying assembly layers, insulation, thermal properties, or moisture-control measures. Similarly, roofing and window specifications may omit essential performance information, while shading devices and envelope junctions may lack adequate detailing (Tunji-Olayeni et al., 2023). Such omissions can complicate cost estimation, construction, and regulatory assessment.

The problem is particularly important given Nigeria's climatic conditions. Warm-humid locations such as Aba, Port Harcourt, and Lagos experience relative humidity levels reported at 70–90%, while solar radiation is reported to average 5.5–6.5 kWh/m²/day (Energy Commission of Nigeria, 2022). Buildings reportedly account for 52% of national electricity consumption, with 60% of this consumption attributed to cooling (National Bureau of Statistics (NBS), 2023). These figures highlight the importance of examining building-envelope design and documentation as part of wider energy-efficiency efforts.

The Building Energy Efficiency Code (BEEC) 2022 provides an important regulatory reference for assessing building-envelope performance (Federal Ministry of Works and Housing, 2022). Reported requirements include a wall U-value of 2.0 W/m²K, a transitional target of 0.6 W/m²K by 2030, a roof U-value of 0.5 W/m²K, and a glazing U-value of 3.0 W/m²K. Other reported provisions include a maximum window-to-wall ratio (WWR) of 30% for commercial buildings, shading projection factors of 0.25 for north–south façades and 0.50 for east–west façades, and daylight provision of 300 lux in 50% of regularly occupied spaces (Federal Ministry of Works and Housing, 2022). The applicability of individual requirements must be determined from the relevant code provisions and building conditions. Ugochukwu et al. (2022) reportedly found that only 3% of 1,200 building approval submissions examined in Abuja included a BEEC compliance sheet or envelope calculation. The original study also reports that buildings may consume 40–60% more energy than simulated (Saka et al., 2024). Such findings highlight the need to examine whether architectural documentation provides sufficient information to assess compliance and communicate design requirements effectively.

The problem extends to architectural education, professional practice, and regulatory assessment. Abiodun and Oladunmoye (2022) reportedly found that only 12% of final-year students in five federal universities could correctly detail an insulated cavity wall at 1:20 scale or a shading device at 1:5 scale with solar geometry. The Nigerian Building and Road Research Institute (NBRRI, 2023) also provides a relevant reference for material-property information used in building documentation. Tunji-Olayeni et al. (2023) reportedly found that 84% of 120 ARCON-registered principals rated recent graduates poorly in roof and shading detailing, while 91% rated them poorly in BIM-based envelope documentation at LOD 350. In 50 Lagos tender drawing sets, the reported omissions included continuous insulation at slab edges in 92%, damp-proof membrane and vapour-barrier positions in 88%, window schedules containing performance data in 95%, and adequately specified shading details in only a minority of drawings. These findings suggest potential weaknesses in the completeness and coordination of envelope documentation.

Regulatory assessment is also relevant. Alao et al. (2024) discuss limitations in building-envelope compliance assessment, while the Nigerian Building Code 2023 and the Core Curriculum and Minimum Academic Standards (CCMAS) 2022 provide relevant regulatory and educational contexts for building performance and sustainable design (Federal Republic of Nigeria, 2023; National Universities Commission [NUC], 2022). Nevertheless, the extent to which building-envelope documentation achieves defined LOD levels and demonstrates compliance with BEEC 2022 and applicable building-code provisions requires systematic assessment.

Although previous studies have addressed BIM adoption, architectural education, professional competence, and regulatory practice, further empirical investigation is needed to establish the level of development achieved in actual architectural working drawings, the extent of demonstrable BEEC compliance, and the factors hindering effective documentation. This study therefore assesses the LOD and BEEC 2022 compliance of building-envelope systems in selected Nigerian architectural projects and proposes a Sustainable Envelope Integration Framework (SEIF) to improve the integration of technical detailing, material information, and compliance-related documentation.

Despite the introduction of BEEC 2022, the Nigerian Building Code 2023, and CCMAS 2022, the adequacy of building-envelope documentation in Nigerian architectural practice remains an important concern

(Federal Ministry of Works and Housing, 2022; Federal Republic of Nigeria, 2023; NUC, 2022). Reported deficiencies include incomplete assembly specifications, missing insulation and moisture-control details, inadequate window schedules, and insufficient shading information (Abiodun and Oladunmoye, 2022; Tunji-Olayeni et al., 2023). The reported finding that only 3% of 1,200 Abuja approval submissions included a BEEC compliance sheet or envelope calculation further raises concerns about the availability of information needed for regulatory assessment (Ugochukwu et al., 2022). However, the extent to which these deficiencies correspond to specific LOD levels and affect demonstrable compliance with applicable energy-efficiency requirements remains insufficiently established. The central problem is therefore the lack of a sufficiently clear empirical assessment of how building-envelope systems are documented in selected Nigerian architectural projects, the levels of development achieved, and the extent to which the documentation demonstrates compliance with BEEC 2022 and relevant Nigerian Building Code provisions. This study addresses the problem by assessing working drawings, identifying documentation challenges, and proposing the Sustainable Envelope Integration Framework (SEIF).

The study aims to assess the Level of Development (LOD) and BEEC 2022 compliance of building-envelope documentation in modern Nigerian architecture and develop a framework for improving its integration with applicable energy-efficiency requirements. The specific objectives are to:

i. Identify and classify contemporary building-envelope systems used in modern Nigerian architecture.

ii. Examine current documentation practices and LOD 200, LOD 300, and LOD 350 in architectural working drawings.

iii. Evaluate the extent of compliance with BEEC 2022 and applicable Nigerian Building Code requirements using a 25-item audit checklist.

iv. Identify challenges affecting effective documentation of sustainable building-envelope systems at LOD 350.

v. Propose a Sustainable Envelope Integration Framework (SEIF) for improving envelope documentation from LOD 200 to LOD 350.

This study is significant to architectural education, professional practice, regulatory assessment, and sustainable building design. In education, it can provide evidence to support the integration of environmental design, technical detailing, and BIM-based documentation into architectural programmes. For practising architects, the proposed 25-item checklist may help identify missing assembly details, material properties, insulation continuity, glazing specifications, and shading information, subject to appropriate validation. For planning and building-control authorities, the findings may support more systematic assessment of envelope documentation against applicable energy-efficiency requirements. The proposed SEIF may also provide a structured approach to integrating LOD assessment, material information, and compliance documentation.

The study has potential environmental and economic relevance because better envelope design and specification may support reduced cooling demand and improved building performance. The reported contribution of buildings to national electricity consumption (NBS, 2023), together with reported cooling-load reductions of 35–45% in GIZ-supported pilot projects in Abuja (Federal Ministry of Works and Housing, 2022), reinforces the importance of investigating this issue. However, actual energy savings cannot be established through drawing audits alone.

The study focuses on external building-envelope systems, including walls, roofs, ground-contact floors, fenestration, shading devices, and green envelope systems. Internal partitions, structural frames, and mechanical, electrical, and plumbing services are excluded, except where they interface directly with the envelope, such as at slab edges and beam-column-wall junctions. Geographically, the study covers selected locations in Nigeria, namely Lagos, Abuja, Port Harcourt, Aba, Umuahia, and Isuikwuato Local Government Area, to examine documentation practices across the selected urban and rural contexts. The documentary assessment covers architectural working drawings, including plans, elevations, sections, details at 1:20, 1:10, and 1:5 scales, door and window schedules, material specifications, and available BEEC compliance documents. The study examines documentation quality, LOD, and demonstrable compliance with applicable energy-efficiency requirements. It does not directly assess construction supervision, as-built conditions, or post-occupancy energy consumption. Its time scope covers working drawings produced between 2020 and 2025, allowing examination of documentation before and after the introduction of BEEC 2022, with due consideration of the regulatory requirements applicable when each drawing was prepared.

LITERATURE REVIEW

Theoretical Framework

Three complementary theoretical perspectives underpin the study: Systems Theory, Performance Theory, and Information Modelling Theory. Together they provide a coherent lens for examining why envelope documentation must move beyond generic representation toward integrated, performance-oriented information at LOD 350 and form the foundation for the proposed Sustainable Envelope Integration Framework [SEIF].

Systems Theory, articulated by von Bertalanffy (1968), conceptualises a building as an open system that continuously exchanges energy, matter, and information with its environment. Within this perspective, the building envelope functions as the primary interface governing

these exchanges. Aksamija (2013) argues that the envelope should therefore be understood and documented as an integrated system of structure, enclosure, and environmental control rather than as a collection of isolated components. Discontinuities at junctions—particularly at slab edges—can produce significant thermal bridging, with studies indicating heat-loss contributions in the order of 15–20 % (ASHRAE, 2022). When working drawings treat walls, roofs, and fenestration as discrete elements without interface details, the systemic character of the envelope is lost. This theoretical insight directly supports the requirement for LOD 350 documentation that captures junctions, attachments, and continuity of performance layers.

Performance Theory emerged from the energy crises of the 1970s and the concurrent development of climate-responsive design. Olgyay's (1963) foundational work framed the envelope as a climate filter whose effectiveness must be quantified. Subsequent standards, notably ASHRAE 90.1, formalised the expectation that drawings and models carry verifiable performance data—U-value, Solar Heat Gain Coefficient (SHGC), Visible Light Transmittance (VLT), and air-infiltration rates (ASHRAE, 2022). Empirical observations reported by Aksamija (2013) suggest that projects documented at LOD 350 with embedded performance tags tend to show closer alignment between design intent and simulated outcomes than those relying on generic LOD 200 representations. BEEC 2022 represents a national application of this performance-oriented paradigm (Federal Ministry of Works and Housing, 2022).

Information Modelling Theory, formalised in ISO 19650-1:2018, treats each building element as a parametric information container rather than a graphical symbol (ISO, 2018). The BIMForum (2023) Level of Development specification operationalises this idea: LOD 200 denotes a generic placeholder; LOD 300 provides specific geometry; LOD 350 adds interface details, attachments, and performance data; and LOD 400 reaches fabrication readiness. Comparative studies indicate substantial variation in the adoption of higher LOD practices across regions, with more advanced markets demonstrating greater capacity for automated performance tagging than many practices in Nigeria (Saka et al., 2024).

Taken together, the three theories suggest that effective envelope documentation requires (a) recognition of the envelope as an integrated system, (b) the inclusion of quantifiable performance parameters, and (c) the structured organisation of that information within a modelling environment capable of supporting LOD 350. The present study draws on this integrated Systems–Performance–Information Modelling perspective to evaluate current Nigerian practice and to inform the proposed Sustainable Envelope Integration Framework (SEIF).

Conceptual Review

Building Envelope Systems

The building envelope is defined as the physical separator between interior and exterior environments (Aksamija, 2013). In the Nigerian context, several envelope configurations are particularly relevant. Opaque walls commonly employ 225 mm hollow sandcrete block, which typically exhibits a U-value in the region of 2.8 W/m²K (NBRRI, 2023)—higher than the BEEC 2022 transitional limit of 2.0 W/m²K. Fenestration frequently relies on single clear glass (approximate U-value 5.8 W/m²K and SHGC 0.86), while BEEC specifies a maximum glazing U-value of 3.0 W/m²K and a window-to-wall ratio (WWR) not exceeding 30 % for commercial buildings (Federal Ministry of Works and Housing, 2022). Roof systems range from conventional metal sheeting to cool roofs (albedo greater than 0.65) and ventilated double roofs, the latter shown in some studies to reduce heat flux substantially (Enete et al., 2021); BEEC requires a roof U-value of 0.5 W/m²K or better. Shading devices are sized according to solar geometry relationships, and BEEC stipulates minimum projection factors of 0.25 for north–south façades and 0.50 for east–west façades. Green envelope systems (living walls and green roofs) introduce additional requirements for root barriers, drainage, and waterproofing that demand detailed interface documentation (Adeyemo et al., 2023).

Documentation of Envelope Systems

Documentation translates design intent into information that can be costed, tendered, and constructed (ARCON, 2023b). International best-practice guidance recommends a hierarchy of scales: overall plans at 1:100 that permit WWR calculation, sections at 1:50, wall build-ups at 1:20, and critical interfaces at 1:5 or larger (BIMForum, 2023; ARCON, 2023b). In much of current Nigerian practice, however, envelope elements continue to be described generically—for example, "225 mm block plastered and painted," "0.55 mm aluminium roofing sheet," or "aluminium sliding window"—without layer composition, thermal properties, or performance data (Tunji-Olayeni et al., 2023). Shading is frequently indicated as a simple projection line rather than a dimensioned, material-specified element with calculated projection factor. This pattern of representation limits the capacity of drawings to support BEEC compliance verification or accurate quantification.

Empirical Review

International Studies

Research in temperate and high-performance contexts has demonstrated the value of detailed envelope documentation. Aksamija (2013), examining a substantial sample of high-performance façades, reported that projects documented at higher LOD levels

experienced fewer disputes related to envelope performance. Jones et al. (2021) found that the introduction of mandatory energy-performance calculations in the United Kingdom was associated with marked improvements in compliance rates. Al-Kodmany (2022) observed that the absence of detailed shading geometry at large scale contributed to significant underperformance relative to design intent. While these studies provide useful benchmarks, their climatic and regulatory contexts differ from those of tropical Nigeria, limiting direct transferability.

Nigerian Studies

A growing body of Nigerian research has examined aspects of envelope performance and documentation, although the studies remain relatively fragmented. Investigations of completed buildings have highlighted high window-to-wall ratios, inadequate shading, and resulting thermal discomfort (Adedokun et al., 2022; Enete et al., 2021). Analyses of working drawings have revealed limited incorporation of solar geometry and interface detailing (Olotuah, 2020). Educational studies indicate that many final-year architecture students struggle to produce detailed cavity-wall or shading-device drawings at appropriate scales, and that climatology teaching is often insufficiently integrated with design studio (Abiodun & Oladunmoye, 2022; Maina, 2015). Professional surveys report that a substantial proportion of principals rate recent graduates as weak in large-scale detailing and BIM-based envelope documentation (Tunji-Olayeni et al., 2023). Regulatory audits have found low rates of inclusion of formal BEEC compliance documentation in approval submissions (Ugochukwu et al., 2020). Studies of green roofs have also noted relatively high rates of post-construction failure, frequently linked to detailing deficiencies (Adeyemo et al., 2023).

Collectively, these studies establish that performance and documentation shortcomings exist across education, practice, and regulation. However, most focus either on completed buildings (rather than the drawings that govern construction) or on general BIM maturity, without systematically mapping specific BEEC parameters-U-values, SHGC, projection factors, air-barrier continuity-onto defined LOD levels. Sample sizes, methodological approaches, and geographic coverage also vary, limiting the generalisability of individual findings.

Regulatory Framework

The regulatory environment in Nigeria has evolved considerably. The National Building Code (NBC) 2023 requires thermal calculations as an appendix to working drawings for buildings exceeding two floors (Federal Republic of Nigeria, 2023). BEEC 2022 establishes mandatory envelope performance thresholds and a compliance checklist for building permits (Federal Ministry of Works and Housing, 2022). The Core Curriculum and Minimum Academic Standards (CCMAS) 2022 calls for the integration of sustainable design and BIM into architecture programmes (National Universities Commission, 2022). ARCON guidelines further indicate progressive LOD expectations linked to different qualification levels (ARCON, 2023a). While these instruments provide a clear policy foundation, the literature suggests that enforcement capacity and the availability of practical verification tools remain constrained.

Challenges to LOD 350 Documentation

Studies of BIM adoption in Nigeria consistently identify several interrelated barriers. These include the limited availability of locally calibrated BIM object libraries, insufficient training in performance-oriented modelling, the cost of software and hardware, and relatively weak regulatory enforcement of documentation standards (Saka et al., 2024). The absence of a comprehensive National Building Specification further complicates the consistent description of envelope assemblies (ARCON, 2023b). These challenges interact: without appropriate material libraries, automated generation of U-value tags at LOD 350 is difficult; without training and enforcement, the incentive to invest in higher LOD documentation remains limited.

Research Gaps

The reviewed literature reveals four interrelated gaps.

Theoretical gap

Systems Theory, Performance Theory, and Information Modelling Theory have largely been applied in isolation. Few studies integrate them into a unified framework that links systemic continuity, quantifiable performance data, and structured information modelling specifically to envelope documentation in a tropical African context.

Empirical gap

International studies are predominantly set in temperate climates and advanced regulatory environments. Nigerian research, while valuable, tends to examine either completed buildings or general BIM practice. No study has systematically mapped the specific performance parameters required by BEEC 2022 (wall and roof U-values, glazing performance, WWR, shading projection factors, air-barrier continuity) against the LOD continuum (200–350) in architectural working drawings.

Methodological gap

Existing assessments often rely on generic questionnaires or binary checks for the presence of a compliance sheet rather than detailed, criterion-

referenced evaluation of drawing content against BEEC requirements and LOD definitions. Locally validated tools and material libraries calibrated to Nigerian construction products remain scarce.

Practical and educational gap

Curriculum guidance allocates relatively limited credit hours to advanced working-drawing and BIM skills, and accreditation processes place greater emphasis on facilities than on the LOD quality of student output. Consequently, a persistent mismatch exists between the generic documentation commonly produced in academic and many professional settings and the performance-oriented documentation required for effective BEEC compliance.

These gaps collectively justify an empirical investigation that evaluates current envelope documentation against both LOD criteria and BEEC 2022 requirements, identifies the principal barriers to higher-quality documentation, and develops a practical framework—supported by a structured audit checklist and locally relevant information resources—to support progression from generic to performance-oriented practice.

METHODOLOGY

The study is guided by pragmatism, which prioritises the research problem and permits the combination of quantitative and qualitative approaches where this best serves understanding of complex built-environment phenomena (Creswell and Creswell, 2018). Ontologically, building-envelope documentation is treated both as an objective artefact whose characteristics (U-values, window-to-wall ratios, Level of Development) can be measured and as a socially constructed professional practice shaped by education, regulation, and market conditions. Epistemologically, knowledge is generated through systematic auditing of drawings and through the perceptions of practitioners and educators. The overall approach is primarily deductive, testing propositions derived from Systems Theory, Performance Theory, and Information Modelling Theory, while remaining open to inductive insights arising from the data, particularly in the development of the proposed framework

Research Design

A convergent parallel mixed-methods design was adopted (Creswell and Creswell, 2018). Quantitative and qualitative strands were conducted concurrently, analysed separately, and integrated at the interpretation stage.

Phase 1 (primary strand) comprised quantitative content analysis of architectural working-drawing sets using a structured 25-item BEEC 2022 / LOD audit checklist. This phase addressed Objectives 2 and 3.

Phase 2 comprised a cross-sectional survey of architects and architecture educators to identify barriers to LOD 350 documentation (Objective 4).

The two strands were triangulated to relate what is missing from the drawings with the reasons stakeholders advance for those omissions. The design is appropriate for studies that combine artefact evaluation with professional perception in the Nigerian context.

Study Area

Nigeria was stratified into three zones selected to capture climatic, regulatory, and urban–rural variation:

Zone A – Lagos (South-West): Warm-humid climate; high concentration of contemporary commercial and high-rise projects; relatively stronger (though still incomplete) engagement with energy-performance regulation.

Zone B – Federal Capital Territory, Abuja (North-Central): Hot semi-arid climate; predominance of institutional and large-scale architecture; site of earlier BEEC pilot activities.

Zone C – Abia State (South-East): Warm-humid climate; includes the commercial centre of Aba, the state capital Umuahia, and the rural–urban transitional area of Isuikwuato Local Government Area. This zone provides contrast in enforcement capacity and in the prevalence of less formally supervised construction.

All three zones fall within climatic regions for which BEEC 2022 requirements are applicable, yet documented enforcement intensity varies, being weakest in Zone C.

Population

Two populations were defined:

Working-drawing sets produced between 2020 and 2025 (post-BEEC 2022). The accessible population comprised approximately 250 sets: 150 academic sets from five NUC-accredited architecture schools (ABSU, FUTO, ESUT, UNILAG, FUTA) and 100 professional sets from ARCON-registered firms operating in Lagos, Abuja, and Abia State.

Stakeholders: ARCON-registered principals (approximately 1,850 nationally) and architecture lecturers teaching relevant studio and climatology courses (approximately 210).

Sample Size

For the drawing audit, Krejcie and Morgan's (1970) table indicated a sample of 152 for a population of 250 at 95 % confidence. Practical constraints of access, time, and the labour-intensive nature of detailed checklist scoring led to the adoption of a final sample of 60 drawing sets (30 academic, 30 professional). While smaller than the statistically ideal size, this number exceeds the

conventional threshold of 30 for the Central Limit Theorem and is consistent with sample sizes used in comparable drawing-audit studies. The reduction limits statistical power for some subgroup analyses and constrains generalisability; these implications are acknowledged in the limitations section.
For the stakeholder survey, Taro Yamane's formula (with a margin of error of 0.08) yielded approximately 142 principals and 70 lecturers. These were adjusted to 120 principals and 30 lecturers (total n = 150) on the basis of accessibility and the decision to focus on lecturers directly involved in working-drawings and climatology courses. The final stakeholder sample size is comparable to those employed in recent Nigerian BIM and architectural-education studies.

Sampling Procedure

Drawing sets were selected through stratified purposive random sampling.
Academic stratum (n = 30): five schools were purposively selected; six sets per school were then randomly drawn from moderation archives (2022–2025). Inclusion required a ground-floor plan, at least two sections, four elevations, and two detailed sections.
Professional stratum (n = 30): ARCON-registered firms with a minimum of five years' practice were purposively identified; sets were then randomly selected within location quotas (Lagos 10, Abuja 10, Aba 5, Umuahia 3, Isuikwuato 2). Inclusion criteria were an ARCON stamp, production date between 2020 and 2025, and buildings of more than two floors (aligned with NBC 2023 thermal-calculation requirements).
Stakeholder sampling combined multi-stage and purposive elements. Principals were stratified by location and randomly selected from the ARCON register; lecturers were purposively selected on the basis of teaching responsibility for ARC 203, ARC 405, or ARC 505 (or equivalent courses).

Research Instruments

Two instruments were developed.

Instrument 1: 25-Item BEEC 2022/LOD Audit Checklist

Derived from BEEC 2022 (Section 4.3), NBC 2023 (Chapter 5), the BIMForum LOD Specification (2023), ISO 19650-1:2018, and ASHRAE 90.1-2022. The checklist is organised into five sections of five items each:
A – Opaque walls (build-up, thermal properties, U-value target, thermal bridging, air/vapour control layers)
B – Roofs (build-up, U-value target, ventilation or reflectance, thermal breaks, large-scale detail)
C – Fenestration (schedule completeness, U-value, SHGC, VLT, WWR, interface detail, daylight indication)
D – Shading (presence, large-scale detail, projection factor calculation, solar geometry, compliance with orientation-specific targets)
E – General / LOD indicators (BEEC compliance table, continuous air-barrier representation, overall LOD classification, BIM-object usage, specification linkage).
Scoring for each item:
0 = Absent
1 = Generic / LOD 200-level representation
2 = Performance-oriented / LOD 350-level representation
Maximum score = 50. A Compliance Index was calculated as (Score / 50) × 100. Provisional interpretation bands were: < 50 % ≈ predominant LOD 200; 50–69 % ≈ partial / LOD 300 characteristics; ≥ 70 % ≈ predominant LOD 350 characteristics.
Where drawings contained incomplete or ambiguous information, the lower score was assigned and the ambiguity recorded. U-values, where not stated, were recalculated from stated or standard material properties using the formula:

$$U = \frac{1}{R_{si} + \sum(d/k) + R_{se}}$$

With surface resistances and conductivity values drawn from NBRRI (2023) data. Window-to-wall ratio and projection factor were calculated from dimensioned information when available.

Instrument 2: Barriers Questionnaire

A 20-item instrument using a five-point Likert scale, organised into educational, technical, regulatory, and economic categories, supplemented by demographic items and an open-ended question requesting suggested actions to move practice from LOD 200 toward LOD 350. Items were adapted from recent Nigerian studies of BIM adoption and architectural education.

Validity

Content validity was assessed by a five-member expert panel (two professors of building technology, one ARCON principal, one planning-authority officer, and one BEEC consultant). The Content Validity Index reached 0.88 for the checklist and 0.90 for the questionnaire, both above the conventional 0.80 threshold. Construct alignment was verified by mapping each checklist item to specific clauses in BEEC 2022 and the BIMForum LOD Specification.

Reliability

A pilot audit of ten drawing sets (excluded from the main sample) was conducted by two independent assessors. Inter-rater reliability yielded Cohen's Kappa = 0.84, indicating almost perfect agreement. The barriers questionnaire was piloted with 20 respondents; overall

Cronbach's alpha was 0.89, with subscale values ranging from 0.81 to 0.88, all above the 0.70 acceptability threshold (Saka et al., 2024; Enete et al., 2024).

Data Collection Procedure

Ethical clearance was obtained from the relevant postgraduate school. Introductory letters were secured from ARCON, NUC, and the planning authorities in the selected locations. Academic drawing sets were obtained from departmental archives with Head of Department permission. Professional sets were collected as anonymised PDF or DWG files under non-disclosure arrangements; limited site visits supplemented collection in Isuikwuato. Each set was audited over a period of approximately two to three hours. The stakeholder survey was administered through a combination of physical distribution (Abia) and online forms (Lagos and Abuja), with two reminder rounds. Target response rate was 85 %.

Data Analysis

Data were analysed using SPSS (version 26) and NVivo.
Research Objective 1: frequencies and percentages of envelope system types.
Research Objective 2: frequency distribution of LOD classifications, cross-tabulation by location and by academic/professional origin, chi-square tests of association ($\alpha = 0.05$).
Research Objective 3: descriptive statistics (mean, standard deviation) for each checklist section, overall Compliance Index, one-sample t-test against the 50 % threshold, and ANOVA for differences across locations and between academic and professional sets ($\alpha = 0.05$).
Research Objective 4: mean scores and Relative Importance Index (RII) for barrier items; thematic analysis of open-ended responses.

Ethical Considerations

The study received institutional ethical approval. Informed consent was obtained from survey participants. Drawing sets were anonymised (ACAD01–ACAD30; PROF01–PROF30). Data were used solely for academic purposes and stored securely. The research adhered to the principle of non-maleficence and to relevant professional guidelines.

Limitations

Several limitations are acknowledged. First, the drawing sample of 60, while adequate for exploratory and descriptive purposes, is smaller than the statistically ideal size of 152; this reduces power for certain subgroup comparisons and limits the generalisability of findings beyond the sampled schools, firms, and locations. Second, U-value assessments were based on stated or standard material properties rather than in-situ measurement (heat-flux or blower-door testing). Third, the study examined LOD with respect to geometric and performance information but did not extend to 4D or 5D BIM dimensions. Fourth, the stakeholder sample, particularly the lecturer subsample, was purposively focused and may not represent the full national population of architecture educators. These constraints are offset to some extent by the high inter-rater reliability of the audit instrument, the use of multiple data sources, and the transparent reporting of procedures, yet they remain relevant to the interpretation of results.

RESULTS

This chapter presents the findings of the study in accordance with the research objectives. Sixty working-drawing sets (30 academic, coded ACAD01–ACAD30, and 30 professional, coded PROF01–PROF30) were audited using the 25-item BEEC 2022/LOD checklist. In addition, 132 valid stakeholder questionnaires were returned (response rate 89.3 %). Data were analysed using SPSS version 26. Results are reported descriptively and, where appropriate, with inferential statistics. Interpretation..

Contemporary Building Envelope Systems (Objective 1)

Table 1 summarises the frequency of envelope systems observed across the 60 drawing sets.
The most frequently documented wall system was 225 mm hollow sandcrete block with plaster (86.7 %). Aluminium long-span roofing without insulation appeared in 80.0 % of sets, and single clear glazing in aluminium frames in 76.7 %. Concrete fascias were the most common shading indication (63.3 %). Higher-performance systems (unitised curtain wall, ventilated or cool roofs, insulated cavity walls, and green envelopes) occurred infrequently and were largely confined to Lagos and Abuja.

Level of Development of Envelope Documentation (Objective 2)

Table 2 presents the distribution of drawing sets according to the LOD classification derived from total checklist scores.
The majority of sets (76.7 %) fell within the LOD 200 range. Twenty per cent were classified as LOD 300, and only two professional sets (3.3 %) reached the LOD 350 threshold. No academic set achieved LOD 350. A chi-square test indicated a statistically significant association between academic/professional origin and LOD category, $\chi^2(2) = 8.76$, $p = .013$. A further chi-square test of location against LOD category was also significant, $\chi^2(4) = 18.42$, $p = .001$. Both LOD 350 sets originated from Lagos.

Table 1: Frequency of Envelope Systems Observed (n=60).

Envelope System	Frequency [n=60]	%	Location Dominance
225mm hollow sandcrete block, plastered	52	86.7%	Aba, Umuahia, Isuikwuato
Aluminium long-span roof 0.55mm no insulation	48	80.0%	All zones
Single clear 6mm aluminium sliding window	46	76.7%	All zones
600mm concrete fascia as shading [no PF]	38	63.3%	Abia
Perforated aluminium screen (aesthetic only)	14	23.3%	Lagos, Abuja
Unitized curtain wall	8	13.3%	Lagos, Eko Atlantic
Ventilated double roof / cool roof	4	6.7%	Abuja
Cavity wall with insulation / ICF / CEB	2	3.3%	Abuja
Green roof / green wall	1	1.7%	Lagos

Table 2: LOD Classification of Envelope Documentation (n=60).

LOD Level	Academic [n=30]	Professional [n=30]	Total [n=60]	Mean Score/50
LOD 200 Generic [Score <25]	27 [90.0%]	19 [63.3%]	46 [76.7%]	16.2
LOD 300 Specific [Score 25-34]	3 [10.0%]	9 [30.0%]	12 [20.0%]	28.4
LOD 350 Performance [Score ≥35]	0 [0.0%]	2 [6.7%]	2 [3.3%]	38.5

Table 3: BEEC Compliance Index by Section (n = 60).

Section	Item Description	Mean	SD	% Compliance	Remark
(A) Opaque Wall	A1 build-up, A2 k-value, A3 U-value ≤2.0, A4 thermal bridge, A5 air barrier	1.84	0.92	18.4%	Non-Compliant
(B) Roof	B6 build-up, B7 U-value ≤0.5, B8 albedo/vent, B9 thermal break, B10 detail 1:10	1.12	0.78	11.2%	Non-Compliant
(C) Fenestration	C11 schedule, C12 U-value ≤3.0, C13 SHGC, C14 WWR ≤30%, C15 interface 1:10	2.05	1.14	20.5%	Non-Compliant
(D) Shading	D16 shown, D17 detail 1:5, D18 PF calc, D19 HSA/VSA, D20 PF ≥0.5/0.25	1.42	0.86	14.2%	Non-Compliant
(E) General/LOD	E21 BEEC table, E22 air barrier diagram, E23 LOD tag, E24 BIM object, E25 spec	0.68	0.54	6.8%	Critical
Overall	Total/50	7.11	2.31	14.22%	Non-Compliant LOD 200

Compliance with BEEC 2022 Requirements (Objective 3)

Table 3 reports mean scores, standard deviations, and percentage compliance for each of the five checklist sections (maximum score per section = 10) and for the overall Compliance Index.

The overall mean Compliance Index was 7.11 out of 50 (14.22 %). A one-sample t-test comparing the mean score against the midpoint value of 25 yielded $t(59) = -48.73$, $p < .001$, indicating that the observed mean was significantly lower than 25.

Section means ranged from 0.68 (General/LOD) to 2.05 (Fenestration). No set recorded a calculated U-value for walls or roofs. Window-to-wall ratio was calculated in only two sets (3.3 %); the mean measured WWR across the sample was 42.6 %. Projection-factor calculations were absent from all sets. A BEEC compliance table appeared in only one set (1.7 %).

One-way ANOVA indicated significant differences in

Table 4: Barriers to LOD 350 (n=132, RII Rank).

Barrier	Mean	RII	Rank	Theme
Absence of BIM object libraries for Nigerian materials (sandcrete k=0.78)	4.51	0.902	1	Technical
Lack of lecturers with BIM/BEEC skills	4.43	0.886	2	Educational
Outdated CCMAS curriculum, 6 credits for Working Drawings, BIM elective	4.41	0.882	3	Educational
Weak enforcement, no BEEC audit checklist at planning authorities	4.38	0.876	4	Regulatory
Inadequate ICT infrastructure, no licensed Autodesk AEC Collection	4.35	0.870	5	Technical
Assessment rewards aesthetics over buildability & LOD	4.21	0.842	6	Educational
High cost of software, poor internet, power outage	4.15	0.830	7	Technical
No National Building Specification for envelope	4.02	0.804	8	Technical
Client unwilling to pay for LOD 350 documentation	3.89	0.778	9	Economic

overall Compliance Index between academic and professional sets, $F(1, 58) = 12.84$, $p = .001$. Professional sets recorded a higher mean (approximately 18.4 %) than academic sets (approximately 10.1 %), although both remained well below the 50 % threshold. A further ANOVA across the three study zones was also significant, $F(2, 57) = 9.21$, $p < .001$. Descriptive means were highest in Lagos (22.1 %), followed by Abuja (16.8 %) and Abia State locations (Aba 9.4 %, Umuahia 8.2 %, Isuikwuato 4.1 %).

Barriers to LOD 350 Documentation (Objective 4)

Table 4 presents the mean scores and Relative Importance Index (RII) values for the highest-ranked barriers reported by the 132 respondents.

All nine barriers recorded mean scores above the midpoint of 3.0 and RII values above 0.75. The highest-ranked barrier was the absence of BIM object libraries calibrated to Nigerian materials (RII = 0.902). Educational factors occupied three of the top six positions. Open-ended responses were coded thematically and reinforced the quantitative ranking, with recurrent references to missing material libraries, limited staff capacity, and the absence of practical compliance tools at planning authorities.

Development of the Sustainable Envelope Integration Framework (Objective 5)

On the basis of the audit results and the ranked barriers, a preliminary conceptual framework—the Sustainable Envelope Integration Framework (SEIF)—was formulated. The framework comprises three interrelated layers (Information, Systems, and Performance) intended to support progression from predominantly LOD 200 documentation toward LOD 350 practice consistent with BEEC 2022 requirements (Figure 1).

Layer 1 – Information Layer [LOD Foundation]: Development of the Nigerian BIM Library. NBRRI (2023) thermal data: sandcrete block k=0.78, render 0.72, XPS 0.034, aluminium 160. Create Revit families with embedded U-value auto-calc: $U = 1/[Rsi+\Sigma(d/k)+Rse]$. This addresses Barrier RII 0.902 Rank 1 and Bridging Strategy S9.

Layer 2 - Systems Layer: Mandatory interface details at 1:5: wall-slab air barrier continuity drawn in red, thermal break, vapour barrier position, DPC. Studio teaching must integrate Climatology [ARC 203] into Working Drawings [ARC 405/505]. This addresses Systems Theory (von Bertalanffy, 1968) and Roof Gap 2.17 and Wet Area Gap 2.38 integration.

Layer 3 - Performance Layer [BEEC Compliance]: Every tender set must contain: (a) WWR calculation table [WWR=Glazing/Gross wall×100 ≤30%], (b) PF calculation [PF=Projection/Height ≥0.5 E-W], (c) U-value tags [wall ≤2.0, roof ≤0.5, glazing ≤3.0], and (d) BEEC checklist Section A-E. This addresses Performance Theory [ASHRAE, 2022; Federal Ministry of Works and Housing, 2022] and ARCON scale compliance Gap 2.03.

The Implementation Path aligned with Bridging Strategies S1-S10: Immediate (S1-S3, RII 0.916-0.942): Mandatory BIM from 200L, standardized template, structured SIWES with ARCON logbook. Short-term (S4-S5, RII 0.898-0.910): TETFund retraining of lecturers, practitioner-led studio. Policy (S6-S8, RII 0.864-0.882): Increase Working Drawing credits from 6 to 12, ICT lab 1:4 ratio with Autodesk AEC, accreditation audit of drawings, not just facilities. Medium-term (S9-S10, RII 0.850-0.856): Detailing library and joint studio with Civil/MEP for clash detection addressing MEP Gap 2.63.

Summary of the findings

The following findings were made from the study:

1. Traditional envelope systems predominated: 86.7 % of sets specified 225 mm hollow sandcrete block walls, 80.0 % specified uninsulated aluminium roofing, and

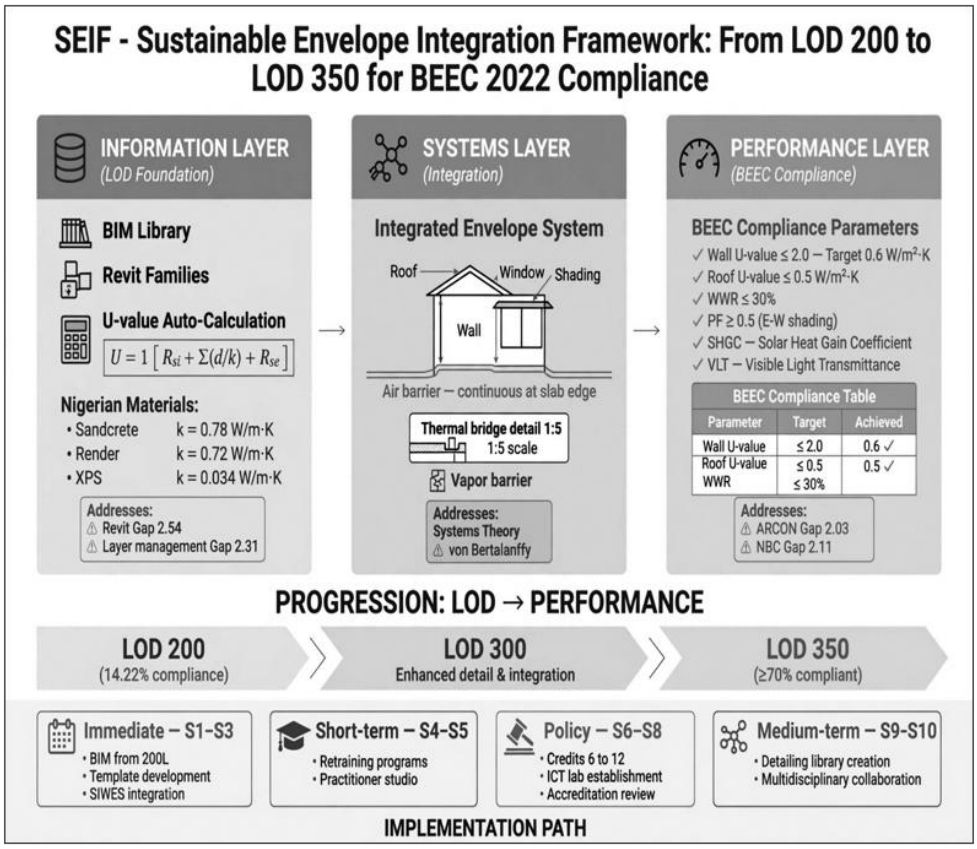

Figure 1: Proposed Conceptual SEIF Framework.

76.7 % specified single clear glazing.
2. 76.7 % of drawing sets were classified as LOD 200, 20.0 % as LOD 300, and 3.3 % as LOD 350. Academic sets showed a higher proportion of LOD 200 documentation (90.0 %) than professional sets (63.3 %).
3. Overall BEEC compliance was low (mean Compliance Index = 14.22 %). Section scores ranged from 6.8 % (General/LOD) to 20.5 % (Fenestration). Calculated U-values and projection factors were almost entirely absent.
4. The most highly ranked barriers were the absence of locally calibrated BIM libraries (RII = 0.902), limited lecturer capacity in BIM and BEEC (RII = 0.886), and curriculum constraints (RII = 0.882).
5. A three-layer conceptual framework (SEIF) was developed from the findings to guide improvement in envelope documentation practice.

DISCUSSION

The discussion is organised around the main patterns observed in envelope systems, Level of Development, BEEC compliance, and the barriers reported by stakeholders. Implications for theory, practice, education, and regulation are considered, and the proposed Sustainable Envelope Integration Framework (SEIF) is introduced as a response to the identified gaps.

Contemporary Envelope Systems and Performance Implications

The audit revealed a predominance of conventional envelope solutions. The majority of drawing sets specified 225 mm hollow sandcrete block walls, uninsulated aluminium roofing, and single clear glazing. Higher-performance alternatives (insulated cavity walls, ventilated or cool roofs, unitised curtain walls, and green envelopes) appeared infrequently and were concentrated in Lagos and Abuja.
When typical material properties reported by NBRRI (2023) are applied, the dominant wall and roof constructions yield U-values substantially higher than the transitional limits set by BEEC 2022. Similarly, the mean window-to-wall ratio observed in the sample exceeded the Code's recommended maximum for commercial buildings, and shading elements were rarely accompanied by projection-factor calculations. These patterns are consistent with earlier observations of high glazing ratios and limited climate-responsive detailing in Nigerian commercial architecture (Adedokun et al., 2022; Olotuah, 2020).
The findings suggest that while contemporary formal languages and selected high-performance systems have entered practice in major urban centres, the technical documentation required to realise their performance potential remains underdeveloped, particularly outside

Lagos and Abuja.

Level of Development of Envelope Documentation

Three-quarters of the audited sets were classified as LOD 200, with only a small minority reaching LOD 350. Academic sets showed a markedly higher proportion of LOD 200 documentation than professional sets. The difference between academic and professional samples was statistically significant, as was the association between location and LOD category.

These results align with previous assessments of BIM maturity in Nigeria, which have reported limited adoption of higher LOD practices compared with the United Kingdom and South Africa (Saka et al., 2024). The near-absence of LOD 350 documentation indicates that most drawings continue to function as generic representations rather than information-rich models capable of supporting automated performance analysis or reliable quantification.

From the perspective of Information Modelling Theory (ISO 19650-1:2018; BIMForum, 2023), the predominance of LOD 200 documentation limits the capacity of the drawing set to carry the geometric, material, and performance data required for energy-compliance verification. The findings also lend support to the argument, drawn from Systems Theory, that treating envelope components as isolated elements rather than as an integrated assembly with defined interfaces reduces the likelihood of continuity in thermal and air-control layers.

BEEC 2022 Compliance

Overall compliance with the 25-item checklist was low. Section scores were highest for fenestration and lowest for general/LOD indicators. Calculated U-values, projection factors, and formal BEEC compliance tables were almost entirely absent. Professional sets achieved higher mean scores than academic sets, and sets from Lagos scored higher than those from Abia State locations; however, all group means remained well below the midpoint of the scale.

The results are broadly consistent with earlier audits that found low rates of formal energy-compliance documentation in approval submissions (Ugochukwu et al., 2020). The near-total absence of performance calculations suggests that current documentation practices do not yet provide planning authorities with the verifiable data required for effective enforcement of BEEC 2022 or the thermal-appendix provisions of NBC 2023.

Barriers to Higher-LOD Documentation

Stakeholders ranked the absence of BIM object libraries calibrated to Nigerian materials as the most significant barrier, followed by limited lecturer capacity in BIM and BEEC, curriculum constraints, and weak regulatory enforcement. Technical and educational factors occupied the highest ranks, while economic considerations ranked lower.

These findings reinforce earlier studies that identified material-library gaps, training deficits, and enforcement limitations as central constraints on BIM adoption in Nigeria (Saka et al., 2024; Tunji-Olayeni et al., 2023). The prominence of educational barriers is particularly relevant given the higher proportion of LOD 200 documentation observed in the academic sample. The relatively lower ranking of client willingness to pay suggests that demand-side factors may be secondary to supply-side and regulatory constraints.

Theoretical Implications

The findings can be read through the integrated Systems–Performance–Information Modelling lens adopted in this study.

1. From a systems perspective, the scarcity of interface details and continuous air-barrier representation indicates that the envelope is still frequently documented as a collection of discrete components rather than as an integrated environmental control system.
2. From a performance perspective, the near-absence of quantified thermal and solar-control data means that drawings rarely move beyond descriptive representation to prescriptive or performance-based specification.
3. From an information-modelling perspective, the dominance of LOD 200 documentation limits the ability of the model or drawing set to support automated checking, quantification, or compliance verification.

The results do not invalidate these theoretical perspectives; rather, they illustrate the practical distance that currently separates Nigerian documentation practice from the expectations embedded in the theories and in contemporary energy codes.

The Sustainable Envelope Integration Framework (SEIF)

In response to the empirical patterns and ranked barriers, a preliminary conceptual framework—the Sustainable Envelope Integration Framework (SEIF)—was developed. The framework comprises three interrelated layers:

1. Information layer – focused on the development of locally calibrated BIM object libraries and templates that embed Nigerian material properties and BEEC parameters.

2. Systems layer – concerned with the consistent representation of interfaces, continuity of control layers, and the integration of climatic analysis into detailed design.

3. Performance layer – directed at the routine inclusion of compliance calculations, structured checklists, and verifiable performance data in tender documentation.

The framework is offered as a structured response to the gaps identified in this study. It remains a conceptual

proposal that requires further development, pilot testing, and validation before its effectiveness can be claimed.

Limitations of the Interpretation

Several limitations of the study qualify the strength of the conclusions that can be drawn. The drawing sample of 60, while sufficient for exploratory analysis, restricts the generalisability of the findings and reduces statistical power for some subgroup comparisons. U-values were calculated from stated or standard material properties rather than measured in situ. The stakeholder sample, particularly the lecturer subsample, was purposively focused and may not fully represent national patterns. These constraints suggest that the results should be regarded as indicative rather than definitive, and that replication with larger and more diverse samples would be valuable.

Conclusion

This study assessed the Level of Development and BEEC 2022 compliance of building-envelope documentation in a sample of academic and professional working drawings from selected Nigerian locations, and examined the barriers perceived by practitioners and educators.

The findings indicate that conventional envelope systems remain dominant, that the great majority of drawings operate at LOD 200, and that overall compliance with the audited BEEC-related criteria is low. Calculated performance data and formal compliance documentation are rare. Stakeholders identify the absence of locally calibrated BIM libraries, limited staff capacity, curriculum constraints, and weak regulatory tools as the most significant barriers.

These patterns are consistent with earlier reports of limited BIM maturity and low rates of energy-compliance documentation in Nigeria. They also highlight a persistent gap between the performance expectations of BEEC 2022 and NBC 2023 and the information currently carried by many working drawings.

In response, the study proposes the Sustainable Envelope Integration Framework (SEIF) as a structured approach to supporting progression from predominantly generic documentation toward more performance-oriented practice. The framework is conceptual and requires further testing.

The results underscore the need for coordinated attention to material information resources, educational capacity, curriculum design, and practical regulatory tools if the documentation standards implied by current energy-performance policy are to be more widely achieved. Future research should pilot elements of the proposed framework, extend the audit to a larger and more geographically diverse sample, and examine the relationship between documentation quality and measured building performance.

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