DOI: https://doi.org/10.67203/ndr.2026.9jy72o88
Roy-Omoni & Okwuazu., NDR 11 (1). 2026. 039-052

NIGERIAN DESIGN REVIEW
Volume 11, Issue 1 | www.ndrjournal.org.ng
JOURNAL OF INDUSTRIAL DESIGN

A SIX-LAYER GRAPHIC FRAMEWORK FOR ENVIRONMENTAL RESPONSIBILITY IN SUSTAINABLE ARCHITECTURAL DESIGN

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Abstract

Environmental responsibility is now central to sustainable architectural practice, yet environmental evidence remains difficult to use in design because assessment results are typically presented in technical formats misaligned with architects' visual, iterative workflows. This study develops a graphical decision-support framework for communicating and applying environmental information throughout the design process. It adopts a conceptual review methodology following Snyder (2019), synthesising literature published between 2018 and 2025 on information visualisation, design cognition, and decision-support systems theory. The review identifies three recurring barriers limiting environmental decision-making: delayed application of life-cycle assessment, fragmentation of environmental and economic evaluation, and poor visual communication of sustainability evidence, alongside a cultural drift toward credential-collecting certification. These findings inform a six-layer graphic framework, baseline disclosure, life-cycle mapping, comparative option testing, threshold-based rating, stakeholder communication, and feedback-driven recalibration, each anchored in a theoretical construct. The framework is demonstrated through a hypothetical mixed-use development in Lagos, Nigeria, and positioned against EDGE, LEED, and BIM-integrated workflows to clarify its relevance in emerging economies. Its principal contribution lies not in generating additional metrics but in translating existing evidence into visually accessible, decision-oriented representations that support earlier, more transparent design choices, while remaining alert to the risk that visualisation itself can oversimplify or mask genuine trade-offs. Although the framework requires empirical validation through practice before its claims can be considered established, it offers a theoretically grounded model for strengthening environmental decision-making, architectural communication, and interdisciplinary collaboration in Nigeria and comparable developing contexts.

Keywords: Graphic communication; Environmental decision support; Sustainable architectural design; Information visualisation; Life-cycle assessment

1. Introduction

The environmental question in architecture has moved from the margins of professional ethics to the centre of design legitimacy. Buildings are material, energy, financial, and social systems operating across long time spans and extensive supply chains: the sector consumes thirty-two per cent of global energy and produces thirty-four per cent of global carbon dioxide emissions, with cement and steel major contributors to emissions and waste (United Nations Environment Programme [UNEP], 2025), and the Intergovernmental Panel on Climate Change (IPCC, 2022) similarly reports 21 per cent of global greenhouse gas emissions in 2019 attributable to buildings, much of it embodied rather than operational. Design decisions are environmental decisions, whether or not the designer treats them that way.

For architects, the difficulty is epistemic as much as moral. Environmental impacts are distributed across time and expressed through metrics that often arrive too late to influence conceptual design; designers think through sketches, while assessment is typically delivered through specialist reports and post hoc compliance narratives. Roberts *et al.* (2020) found that life cycle assessment is commonly introduced once major design moves have already been fixed, so rigorous environmental accountability is often demanded only after the decisions that mattered most have already been made.

This paper reworks the idea of a graphic approach to environmental responsibility for contemporary sustainable design. Its central argument is that environmental responsibility becomes actionable when translated into visual and comparative formats that mirror how architects actually design, letting teams compare materials and test alternatives in near real time. Hollberg *et al.* (2021) show that visualisation is increasingly central to interpreting life-cycle assessment results, though harmonised guidance remains absent, and Apellániz *et al.* (2024) show that interactive three-dimensional dashboards improve stakeholders' understanding of environmental results. Neither claim has been tested across the range of contexts a general framework would need to serve, a limitation this paper treats as a reason for explicit theoretical grounding.

This study addresses one research question: how can a theoretically grounded graphic framework improve environmental decision-making throughout the design process? It establishes theoretical foundations, explains the review methodology, synthesises the literature, develops a six-layer framework, and demonstrates its application through an illustrative Nigerian case positioned against existing certification systems.

2. Theoretical Framework

Before the literature on sustainability tools can be synthesised into a workable framework, its theoretical basis needs stating. Three bodies of theory converge on the same conclusion: visual

representation is not a neutral carrier of pre-existing information but an active determinant of what a designer can perceive, reason about, and decide.

2.1 Information Visualisation and Visual Communication Theory

The first body of theory concerns information visualisation itself. Schloss (2025) shows that observers do not passively receive a visualisation's content; they perceive visual features, map them onto intended concepts, and construct an interpretation shaped by prior knowledge and bias, meaning a life-cycle chart is only as informative as the alignment between its encoding and its reader. Mavros *et al.* (2022) extend this concern to architectural practice, arguing spatial and perceptual cognition research remains poorly integrated into the tools architects are given; visual communication in architecture is constitutive of design reasoning, not merely illustrative of it. This draws on a wider graphic-design lineage: Tufte (2023) and Ware (2021) established that graphical excellence means maximising data conveyed per unit of ink and that perceptual principles should govern encoding; Munzner (2020) and Cairo (2019) show that the same chart form can clarify or distort a claim; and Börner *et al.* (2019) show that visualisation literacy is itself unevenly distributed among audiences, a caution carried into Section 5.

2.2 Design Cognition

The second body of theory concerns design cognition, the study of how designers think as they design. Architectural design proceeds through externalised representations, sketches and comparative layouts that designers read back into new ideas as they draw them, rather than through verbal or numerical reasoning alone; Mavros *et al.* (2022) note that architects are increasingly expected to hold in mind long causal chains between decisions and downstream consequences not directly perceivable at the point of decision. A graphic framework must therefore work with this externalised, iterative mode of reasoning, presenting evidence that can be sketched over and revised, rather than requiring translation out of a specialist register first.

2.3 Decision-Support Systems Theory

The third body of theory is decision-support systems research, developed in management science and increasingly adapted to architecture. Schubert *et al.* (2023) characterise architectural design problems as open and only partially structured, with such systems furnishing decision-makers with process-integrated information rather than resolving the decision itself; crucially, most remain reactive, interrupting the sketch-and-revise rhythm central to design cognition. Padilla *et al.* (2018) supply the mechanism explaining why this matters: their review finds consistent support for a dual-process account in which viewers move between fast, heuristic interpretation and slower, deliberate reasoning, and a visualisation's design determines which process it recruits. A dashboard demanding effortful interpretation when a designer is sketching will not be used when it matters most, while one supporting rapid comparison risks the oversimplification discussed later, a trade-off any framework must manage deliberately.

Collectively, these perspectives provide the framework's intellectual basis: visualisation theory explains how evidence can be represented meaningfully, design cognition explains why architects depend on external representations, and decision-support theory shows information works best integrated into decision-making rather than presented as retrospective compliance. The six-layer framework is therefore a theoretically grounded structure, not an organisational model drawn loosely from the literature.

3. Method

3.1 A Conceptual Review, Defined

This study adopts a conceptual review methodology, in the sense set out by Snyder (2019): a review synthesising a fragmented body of knowledge into a new conceptual structure, rather than testing a single intervention empirically. This differs from a systematic review, which answers a narrow question through an exhaustive, protocol-driven search, and from a purely narrative review, which typically lacks an explicit search strategy; a conceptual review sits between the two, applying a transparent, auditable search process while retaining the interpretive latitude needed to build theory across disciplinary boundaries, a combination suited to a problem that is partly methodological, inherently interdisciplinary, and better served by synthesis than by measurement.

3.2 Search Strategy and Selection Criteria

The search was conducted across three databases, Scopus, Web of Science, and Google Scholar, combining the terms life-cycle assessment, life-cycle costing, building information modelling, dashboard visualisation, green certification, decision support, design cognition, and information visualisation, each paired with architecture or building design, restricted to peer-reviewed articles published between January 2018 and mid-2025, a window capturing the period in which embodied-carbon accounting, dashboard analytics, and BIM-integrated assessment matured. Two international assessment reports (IPCC, 2022; UNEP, 2025) and one institutional guidance document (GSA, 2025) were included outside this window as authoritative baselines. Records were included where they addressed, empirically or conceptually, the timing of environmental assessment relative to design decisions, the integration or fragmentation of environmental and economic evaluation, or the visual communication of environmental results; purely technical accuracy improvements, non-English sources, and conference abstracts lacking full peer-reviewed text were excluded.

This process yielded an initial pool of approximately ninety records after de-duplication, screened first by title and abstract and then by full text. Fourteen sources were retained as the core evidentiary base for Section 4, supplemented by additional sources grounding the theoretical framework in Section 2, a deliberately modest base reflecting conceptual synthesis rather than exhaustive coverage.

3.3 Synthesis and Framework Derivation

Synthesis proceeded thematically. Each retained source was coded for the failure mode it reported, timing, fragmentation, representation, interoperability, or a cultural drift toward credential-collection, with codes grouped inductively and checked against the theoretical constructs in Section 2 (Snyder, 2019), then mapped onto a corresponding framework layer: timing onto baseline disclosure and life-cycle mapping, since both establish the scope and hotspots that make early intervention possible; fragmentation onto comparative option testing, the layer holding environmental and economic criteria together; representation onto threshold-based rating, since layered scorecards were the recurring corrective against opaque single-score outputs; interoperability onto stakeholder communication, since cross-professional dashboards were the recurring response to siloed data; and the cultural drift toward credential-collection onto feedback and recalibration, since a closed post-occupancy loop was the recurring corrective against static, box-ticking certification. This derivation is stated explicitly so each layer in Section 5 can be traced back to the evidence that justifies its inclusion.

4. Literature Review: Barriers Facing Practice

The thematic synthesis revealed four interrelated barriers limiting the effective use of environmental assessment in design decisions. Although practice benefits from increasingly sophisticated assessment tools, these frequently fail to influence the earliest, most consequential design stages, revealing broader challenges of timing, integration, communication, and implementation, discussed below alongside areas of disagreement in the literature.

4.1 Timing

Environmental assessment continues to exert limited influence on early design decisions because life-cycle assessment (LCA) is frequently introduced after major design parameters have already been established. Roberts *et al.* (2020) found that delayed implementation reduces opportunities for meaningful optimisation, while Fnais *et al.* (2022) attribute this to substantial data requirements and limited integration within conceptual workflows.

4.2 Fragmentation and Representation

Environmental assessment remains fragmented across environmental, economic, and technical domains; energy simulation, life-cycle costing, and certification are commonly undertaken as separate exercises despite their interdependence, and Viscuso *et al.* (2022) show that integrating life-cycle assessment with life-cycle costing within BIM environments improves evaluation of competing alternatives by weighing consequences simultaneously. Communication compounds the problem: conventional assessment reports prioritise technical completeness over design usability, making evidence hard for designers and clients to interpret during iterative decision-making. Hollberg *et al.* (2021) identify the absence of harmonised

visualisation approaches for building LCA, whereas Apellániz *et al.* (2024) show interactive dashboards substantially improve interpretation and stakeholder engagement.

4.3 Interoperability and Professional Culture

Although BIM has become an important platform for integrating sustainability assessment, implementation remains constrained by inconsistent data standards, interoperability limitations, and variable model quality, challenges Akbari *et al.* (2024) continue to limit its integration into everyday workflows despite rapid technological development. Beyond such technical limitations, sustainable assessment also faces organisational challenges: certification systems may encourage compliance-oriented practices where accumulating credits takes precedence over holistic reasoning, and Olanrewaju *et al.* (2024) show that existing systems continue to privilege operational performance over embodied and circular impacts, limiting comprehensive evaluation.

4.4 Contested Findings and the Limits of the Evidence

A fair reading of this literature must acknowledge where it disagrees with itself. Akbari *et al.* (2024) report that BIM-linked research is expanding rapidly. Yet, the same review notes that interoperability failures persist despite that growth, suggesting the barrier may be organisational rather than purely technical, a possibility the technically framed literature tends to underplay. Hollberg *et al.* (2021) present a related difficulty: their finding that visualisation aids interpretation rests on a body of work that has not itself agreed how such visualisation should be done, since the review's own conclusion is that harmonised guidance is absent, making the claim a promising but unsettled hypothesis. Apellániz et al.'s (2024) dashboard benefits were demonstrated within a specific software context whose generalisability to less-resourced settings, including much of the Nigerian market, cannot be assumed. The literature's geographic concentration deserves separate note: Roberts *et al.* (2020) and Fnais *et al.* (2022) draw predominantly on European and North American material, where assessment occurs too late in an established workflow, whereas in Nigeria it is largely absent altogether; by early 2025, cumulative EDGE-certified floor space stood at just over 800,000 square metres (Green Building Council Nigeria [GBCN], 2025; International Finance Corporation [IFC], 2024), a small fraction of total building stock. Lateness and absence are related but distinct problems, and a framework built solely to address the former risks irrelevance.

4.5 The Risks of Visualisation: Bias and Oversimplification

A graphic approach carries its own hazards, and honesty about them is a precondition for taking it seriously. Padilla *et al.* (2018) dual-process account indicates that visualisations recruiting fast, heuristic interpretation are more persuasive but also more susceptible to manipulation than those demanding slower reasoning, and Schloss (2025) shows colour and spatial encoding carry semantic associations regardless of intent, so a scorecard's colours can imply confidence the data do not warrant. The practical risk is visual greenwashing: a polished, traffic-light

dashboard can create the appearance of rigorous accounting while masking the operational bias that Olanrewaju *et al.* (2024) document, in which credits skew toward operational performance and away from embodied concerns. Any graphic framework must be judged not only by whether it makes information visible, but by whether it makes uncertainty equally visible, a standard Section 5's framework attempts to meet without claiming full resolution.

5. The Six-Layer Graphic Framework: From Whole-Life Responsibility to a Theoretically Anchored Model

Environmental responsibility in architecture has historically been framed narrowly, as energy efficiency, ecological sensitivity, or compliance with a rating system; each captures something real, and each is partial. Recent literature favours whole-life thinking instead, treating buildings as dynamic assemblages spanning extraction, manufacture, transport, construction, operation, and end-of-life (Fnais et al., 2022): an efficient building can still perform poorly once material impacts and demolition burdens are counted, with cement and steel alone accounting for 18 per cent of building-sector emissions in 2019 (IPCC, 2022). Whole-life responsibility is therefore anticipatory, comparative, and multi-scalar, a complexity a verbal or tabular report struggles to convey, so the evidence must become legible in design terms.

A graphic approach, properly understood, is not a matter of charts and visual polish. As Section 2 has argued, it treats representation as a mode of inquiry, diagrams and comparative schematics that make environmental relations visible and arguable, disclosing burdens, supporting comparison, and communicating uncertainty honestly. None of this is automatically virtuous, since a poorly designed chart can disguise marginal differences as categorical leaps, precisely the bias risk set out in Section 4.5. The task is to design visual systems that raise environmental literacy without manufacturing false confidence, and architecture, already schooled in hierarchy and sequencing, is well placed for it.

Building on the theoretical grounding of Section 2 and the synthesis method of Section 3, the paper proposes a six-layer graphic framework for environmentally responsible design, summarised in Table 1. The framework is intentionally platform-independent: rather than a proprietary software application or certification instrument, it is a conceptual visual structure implementable within BIM environments, interactive dashboards, or low-technology settings using manually prepared comparison boards, increasing its applicability across resource-constrained firms typical of much of the Nigerian and wider African market.

Table 1: Summary of the Proposed Six-Layer Graphic Framework, with Theoretical Anchoring

Layer	Primary Purpose	Typical Graphic Forms	Primary Theoretical Anchor
1. Baseline disclosure	Define scope, boundaries, assumptions, and context.	Boundary diagrams, project summary panels, life-cycle maps	Decision-support theory: scope as precondition for judgement (GSA, 2025; Schubert et al., 2023)
2. Life-cycle mapping	Locate environmental hotspots across stages and elements.	Stacked bars, heat maps, flow diagrams	Visualisation theory: perceptual mapping of magnitude and location (Schloss, 2025)
3. Comparative option testing	Compare design alternatives at the concept and development stages.	Option matrices, radar charts, side-by-side dashboards	Design cognition: externalised reasoning (Mavros et al., 2022)
4. Threshold-based rating	Judge options against carbon, energy, circularity, or policy targets.	Layered scorecards, threshold bands	Decision-support and bias research: transparent judgement (Padilla et al., 2018; Olanrewaju et al., 2024)
5. Stakeholder communication	Support interdisciplinary review and client understanding.	Narrative dashboards, annotated model views, and decision boards	Visualisation and communication theory (Apellániz et al., 2024; Schloss, 2025)
6. Feedback and recalibration	Link post-occupancy evidence to future design improvement.	Performance timelines, variance charts, lessons-learned maps	Decision-support theory: closed-loop correction (Padilla et al., 2018; Fnais et al., 2022)

As Table 1 summarises, the six layers work in three pairs, moving from disclosure (fixing scope, then locating where burdens cluster) to judgment (comparing real design alternatives, then rating them against layered thresholds rather than a single opaque badge, directly answering the bias risk set out in Section 4.5), to accountability over time (extending legibility to engineers, clients, and regulators, then closing the loop with post-occupancy feedback, the corrective step dual-process theory suggests is otherwise missing from one-off assessments). Together, the layers treat environmental responsibility as an iterative visual practice rather than a terminal report, translating evidence that life-cycle assessment, costing, BIM, and certification already generate into design-relevant judgement, without replacing any of those systems.

6. Framework Validation Through Illustrative Application and Comparative Positioning

Conceptual frameworks require a demonstration of their practical relevance, even where empirical validation lies beyond the scope. Accordingly, the six-layer framework is illustrated through a hypothetical Nigerian project and evaluated against established decision-support and

certification systems, not to claim empirical verification but to demonstrate its operational logic, an analytical validation appropriate to a conceptual framework.

6.1 Walking Through the Layers

Baseline disclosure would begin with the architect and client agreeing on a project boundary from material extraction to practical completion, excluding tenant fit-out, against a minimum target of EDGE Certified status; a boundary diagram would make explicit what is and is not counted, addressing the transparency gap repeatedly identified in the literature. Life-cycle mapping would then produce a heat map across structure, envelope, and operational energy; embodied carbon in imported reinforced concrete and glazing dominates for much of the year, given the building's reliance on natural ventilation, consistent with IPCC's (2022) finding on embodied emissions, reframing the conversation away from the operational-energy-only reading a percentage-savings certificate might otherwise encourage.

Comparative option testing would set a radar chart comparing three structural options, imported reinforced concrete, hybrid masonry, and low-carbon laterite block already used in southwestern Nigeria, against carbon, cost, and labour availability, addressing the fragmentation problem Viscuso *et al.* (2022) describe. Threshold-based rating would then present a layered scorecard against EDGE's tiers, separately for energy, water, and embodied carbon rather than a single badge, answering Olanrewaju et al.'s (2024) finding that single-score certification can mask which criterion is driving a rating.

Stakeholder communication would translate that scorecard into an annotated dashboard for the client and the EDGE auditor, supporting the kind of cross-professional legibility Apellániz *et al.* (2024) associate with interactive dashboards. Finally, feedback and recalibration would feed post-occupancy metering data back into the life-cycle map, testing whether the embodied-carbon assumptions held under Lagos's actual operating conditions, in the spirit of the dynamic practice Fnais *et al.* (2022) call for, the step where the framework is most exposed to correction: if the assumptions do not hold, recalibration lets the next project inherit a better estimate.

6.2 Comparative Evaluation of the Proposed Framework

Positioned against EDGE and LEED, the two certification systems most active in the Nigerian market, the six-layer framework does not compete for the same role. EDGE offers a rapid, affordable route to a verifiable certificate, a genuine strength where cost has historically discouraged smaller developers (IFC, 2024). Still, it typically enters at design development, once a scheme is substantially fixed, communicating results through a summary figure rather than the layered comparisons a design team needs while options remain open. LEED shares this limitation, and its heavier documentation burden and reliance on internationally sourced material credits sit awkwardly against Nigerian supply chains, consistent with the operational bias Olanrewaju *et al.* (2024) document. The six-layer framework is therefore best understood

as a design-stage complement upstream of certification, translating the same data EDGE or LEED will eventually audit into a usable form while the design remains malleable.

Table 2: Comparative Evaluation of Environmental Decision-Support Approaches

Criterion |	Proposed Framework |	EDGE |	LEED |	BIM-LCA
Criterion	**Proposed Six-Layer Framework**	**EDGE**	**LEED**	**BIM-LCA Workflow**
Primary purpose	Design-stage environmental decision support	Green building certification	Sustainability certification	Environmental assessment
Stage of application	Early concept through post-occupancy	Mainly design development	Design development and documentation	Design development
Visual communication	High	Moderate	Moderate	Variable
Whole-life integration	High	Moderate	Moderate	High
Stakeholder communication	High	Moderate	Moderate	Low–Moderate
Flexibility for Nigerian practice	High	High	Moderate	Low
Cost of implementation	Low–Moderate	Moderate	High	High
Principal contribution	Continuous visual decision support	Performance certification	Sustainability benchmarking	Environmental analysis

The comparison demonstrates that the proposed framework complements rather than replaces existing systems. Whereas EDGE, LEED, and BIM-LCA primarily evaluate performance or facilitate certification, the proposed framework improves the communication of environmental evidence during design decision-making, particularly relevant within Nigerian practices where limited resources constrain the adoption of digital platforms.

7. Discussion

The proposed framework contributes to sustainable architectural research by repositioning graphic communication as an active component of environmental decision-making, integrating information visualisation, design cognition, and decision-support systems into a unified structure whose greatest contribution lies in improving the communication of environmental evidence before critical decisions become fixed.

7.1 Balancing Simplicity, Accuracy, and Practical Reach

Effective environmental communication requires balancing visual simplicity and analytical completeness: simplified graphics improve accessibility, but excessive simplification may conceal uncertainty or exaggerate differences (Padilla et al., 2018; Schloss, 2025), so visualisations should communicate uncertainty alongside performance, keeping professional judgement central. This balance matters most in emerging economies, where resources remain unevenly distributed and many Nigerian practices rely on modest digital infrastructure despite BIM-based assessment advancing internationally (Akbari et al., 2024); the framework therefore prioritises conceptual flexibility over technological dependence, implementable through advanced platforms or conventional techniques such as manually prepared comparison boards.

8. Limitations

The paper's own limits are worth stating plainly. The review is conceptual rather than systematic; its core evidentiary base of fourteen cited sources, from an initial pool of roughly ninety records, is deliberately modest and interpretive rather than exhaustive, in keeping with the method in Section 3. The six-layer framework has been derived from, and theoretically anchored against, that literature, but has not been tested on an instrumented project; the application in Section 6 is explicitly hypothetical, and its plausibility should not be mistaken for empirical validation. The paper offers no universal weighting for environmental criteria, since such weightings are inescapably contextual, and concentrates on environmental and economic dimensions, leaving fuller integration of social sustainability indicators to future work.

Its international relevance nonetheless lies in its portability: decarbonisation and evidence-based design are common pressures across the global construction sector, and the claim advanced here should travel reasonably well, that sustainable design improves once environmental evidence becomes visually comparative and oriented to the whole life of the building.

9. Conclusion

This study has shown that environmental responsibility in architecture depends not only on generating reliable environmental data but on communicating that evidence in forms that support design decision-making. Through a conceptually rigorous review grounded in information visualisation, design cognition, and decision-support systems, it developed a six-layer graphic framework integrating environmental assessment with architectural reasoning, one that complements rather than replaces existing certification tools by improving the interpretation, comparison, and communication of environmental information throughout the design process.

The illustrative Nigerian case demonstrates the framework's potential relevance within emerging economies, where environmental assessment remains unevenly adopted. Although empirical validation remains necessary, the analytical comparison undertaken here indicates practical advantages for earlier environmental judgement, interdisciplinary collaboration, and transparent decision-making.

Future research should evaluate the framework through applied design studios and post-occupancy investigations across different institutional contexts, providing empirical evidence of its effectiveness and supporting further refinement of graphic decision-support methods.

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