Developing a Context Specific Framework for Green Architecture for Thermal Performance in Abuja's Central Business District

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Abstract
Abuja's high-rise office buildings are frequently criticised for poor orientation, an overuse of glazing and insufficient climate-responsive design, features that lead to excessive solar heat gain, higher cooling demand, reduced indoor thermal comfort and increased energy use. In four carefully selected high-rise office buildings in Abuja's Central Business District, this study assesses the use of green architecture design strategies to improve thermal performance. Adopting a mixed-methods approach, it combines qualitative evidence from field observation and building surveys with quantitative data from questionnaires completed by 82 architects and built-environment professionals. The study identifies the green strategies professionals are aware of, assesses the degree to which they are applied, and analyses the barriers inhibiting their use and the success factors that would encourage adoption. Twenty-three strategies were assessed. Double or triple glazing (Mean = 3.52), fixed external shading devices (Mean = 3.41) and building form and orientation (Mean = 3.28) recorded the highest awareness, but actual application was consistently lower, and every strategy showed a knowledge score above its integration score. The most-applied strategies were building form and orientation (Mean = 3.18) and fixed external shading (Mean = 3.05), and even these barely reached the mid-point of the scale. High initial capital cost (Mean = 3.61), lack of demand or awareness (Mean = 3.42) and a focus on aesthetics over performance (Mean = 3.35) were the leading barriers, while stringent performance-based energy codes (Mean = 3.68), life-cycle cost analysis (Mean = 3.55) and education and cross-disciplinary training (Mean = 3.49) were rated the strongest enablers. The findings indicate that thermal comfort can be substantially improved, and heat gain significantly reduced, by the deliberate and coordinated implementation of passive green strategies, and the study closes with specific recommendations for architects, developers and policymakers.

Keywords: *green architecture, thermal performance, high-rise, office building, passive design, sustainable building design, building envelope, solar shading.*

1.0 Introduction

The increasing global demand for energy-efficient and climate-responsive buildings has intensified academic and professional interest in sustainable design. The building sector accounts for roughly one-third of global energy consumption and nearly 28% of energy-related CO_2 emissions, making it central to climate-mitigation strategy (International Energy Agency, 2022; UNEP, 2023). In tropical regions such as Nigeria, where high temperatures, intense solar radiation and seasonal humidity strongly affect indoor comfort, the design of high-rise office buildings demands careful attention to thermal performance (Adeyemi & Lawal, 2022; Oguegbu et al., 2023). Contemporary practice increasingly recognises that conventional facade systems and glass-dominated skyscraper designs perform poorly under tropical conditions, producing substantial heat gain, elevated cooling loads and reduced occupant comfort (Boadu et al., 2023; Zhang & Wang, 2022). High-rise office buildings are especially vulnerable because of their large facade surface area, the vertical stacking of occupied space and high internal gains from equipment and occupancy (Okeke & Oyenuga, 2024; Peng et al., 2024). Studies across West Africa and other tropical cities have consistently shown that poorly adapted envelopes drive excessive reliance on mechanical cooling, raise operating costs and increase carbon emissions (Agyekum & Fofie, 2021; Lim & Chan, 2022; Mamman & Garba, 2021). Green architecture — also called sustainable or bioclimatic design — emphasises optimising building orientation, enhancing natural and mixed-mode ventilation, minimising solar heat gain through shading and high-performance glazing, and improving the thermal efficiency of the envelope (Gibberd, 2024). Evidence from Singapore, Malaysia, Ghana and other tropical contexts shows that integrating passive and hybrid strategies can significantly cut cooling-energy demand while improving indoor environmental quality. In Abuja, the rapid proliferation of high-rise commercial development has coincided with rising air-conditioning energy use. Iconic towers such as the NNPC Towers, BOI Tower II and the World Trade Center exemplify the city's vertical growth, yet many rely on highly glazed curtain walls, minimal external shading and orientations that prioritise appearance over climatic response (Eneh & Okey, 2021; Mamman & Garba, 2021). A review of energy-efficiency strategies for office buildings identified 29 measures across the pre-construction, construction and post-construction stages, with envelope systems, orientation, renewable-energy integration and daylighting among the most implemented (Erebor, Ibem, Ezema & Sholanke, 2021). The result in Abuja is persistent indoor thermal discomfort, high operating cost and missed opportunities for sustainability leadership. Despite the growing global literature, empirical research specifically examining the knowledge, integration, barriers and enabling factors of green architecture strategies for thermal performance in Abuja's high-rise office buildings remains limited. This study addresses that gap. It systematically evaluates 23 green architecture strategies through a structured questionnaire administered to built-environment professionals, examines the extent of their current integration, identifies the barriers that inhibit adoption, and investigates the factors that facilitate successful implementation, with the aim of guiding architects, developers, facility managers and policymakers toward more climate-responsive high-rise design in Abuja and comparable tropical cities.

2.0 Green Architecture in the Tropical High-Rise

The glazed curtain-wall tower is a twentieth-century invention exported worldwide with little regard for climate. In the tropics its weaknesses are acute: a fully glazed skin admits solar radiation directly into the occupied space, so that cooling plant must continuously remove heat the facade should never have let in. The green-architecture response is not to abandon the tall office building but to redesign its skin and section so that the building modifies the climate before mechanical systems are asked to finish the job. This is the tradition of the bioclimatic skyscraper set out by Ken Yeang in towers such as Menara Mesiniaga, and demonstrated at scale in Norman Foster's Commerzbank in Frankfurt, whose sky gardens and naturally ventilated cavity show that height and passive strategy are not incompatible. The strategies examined in this study are the working vocabulary of that tradition.

Abuja's climate sets the terms of the problem. Table 1 summarises its defining features and their design implications; the combination of intense, high-angle solar radiation and sustained daytime heat is precisely what makes external shading, careful orientation and a considered envelope decisive rather than optional.

Table 1: Climatic characteristics of Abuja and their design implications

Climatic parameter	Characteristic in Abuja	Design implication
Climate type	Tropical savannah (Köppen Aw)	Sustained cooling demand for most of the year
Daytime temperature	Often exceeds 30 °C	High sensible-heat load on glazed facades
Solar radiation	Intense, with high sun angles	Overhangs, shading and orientation are decisive
Seasons	Distinct wet and dry (harmattan) seasons	The envelope must handle both heat and glare
Humidity	Moderate to high in the wet season	Mixed-mode ventilation is viable in cooler periods

Source: compiled by the authors from Adeyemi & Lawal (2022) and Bello & Balami (2025).

Figure 1 shows how the individual strategies combine in the section of a climate-responsive tall facade: external shading intercepts the sun before it reaches the glass, low-emissivity glazing and insulated spandrels limit what remains, a ventilated double-skin cavity carries heat away by the stack effect, planted sky terraces temper the microclimate, and a cool roof carrying photovoltaics closes the section at the top. Mechanical cooling then handles only the residual load rather than the whole of it.

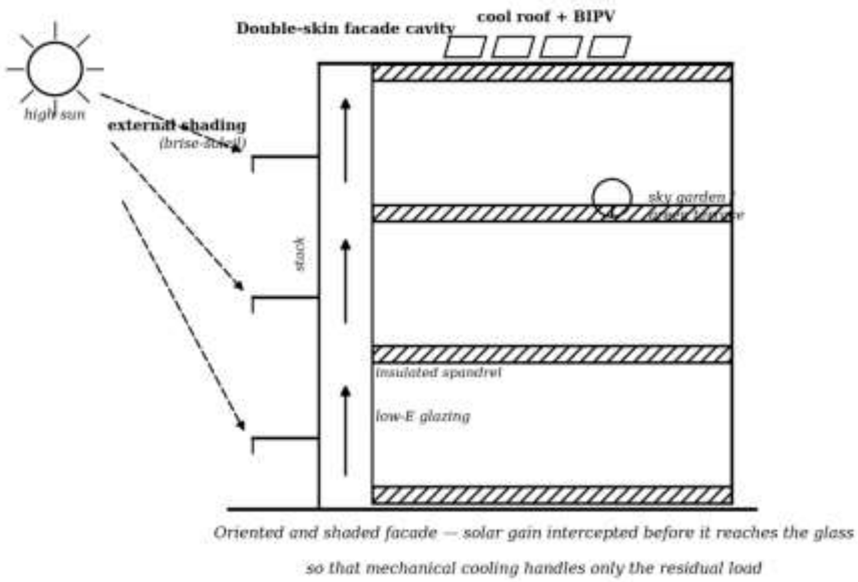

Figure 1: Section through a climate-responsive high-rise facade, integrating external shading, low-E glazing, insulated spandrels, a ventilated double-skin cavity, sky gardens and a cool roof with photovoltaics

Source: Authors' construction (2026).

The 23 strategies assessed are most usefully grouped into five families acting on different parts of the heat problem, set out in Table 2 and Figure 2. The classification matters because the families face different adoption conditions — envelope and shading decisions are largely architectural and early, while systems and renewables depend on capital and expertise — a distinction the results bear out.

Table 2: A classification of the green architecture strategies assessed

Strategy family	Thermal role	Representative strategies assessed in this study
Envelope and glazing	Limit conductive and radiative gain through the skin	Double / triple glazing; low-E coatings; thermal breaks; insulated spandrels; smart glazing
Shading and form	Intercept solar radiation before it reaches the glass	Fixed external shading; adaptive shading; building form & orientation; reflective facades
Ventilation	Remove heat with air movement, not only refrigeration	Natural, mixed-mode, night-purge and displacement ventilation; double-skin facades
Roof and greenery	Cut roof gain and temper the microclimate	Cool roofs; green roofs & sky terraces; sky gardens
Systems and renewables	Meet and offset the residual load efficiently	High-efficiency HVAC; BIPV; chilled beams; ground-source heat pumps; performance simulation

Source: Authors' construction (2026).

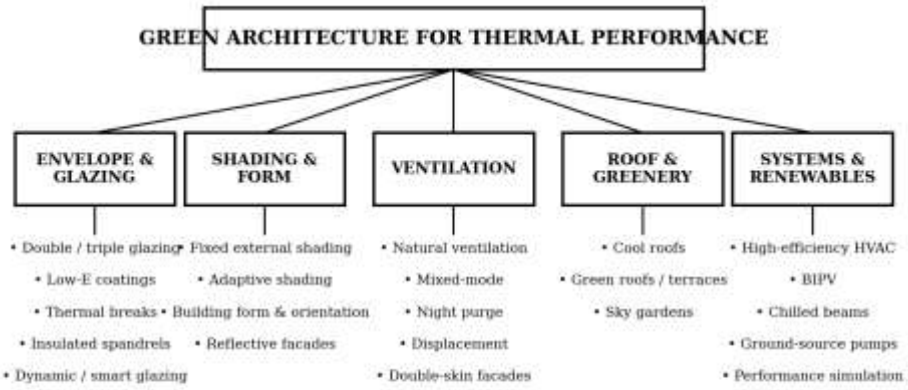

Figure 2: The five strategy families and their representative strategies
Source: Authors' construction (2026).

3.0 Methodology

The research employed a mixed-methods approach integrating quantitative survey data with qualitative observational evidence. It centred on four prominent high-rise office buildings in Abuja — the NNPC Towers, BOI Tower II, the World Trade Center (Commercial Tower) and the Federal Ministry of Finance Headquarters — chosen for their height (exceeding ten floors), their commercial function, their accessibility and their representation of contemporary practice in the Central Business District. The study area falls within the tropical savannah zone, with high daytime temperatures often exceeding 30 °C, intense solar radiation and distinct wet and dry seasons, providing a representative context for examining the interaction of climate, design and thermal performance.

Architects, engineers and facility managers engaged in the design, construction or management of high-rise offices formed the focus group. A total of 120 structured questionnaires were distributed and 82 accurately completed and returned, a 68.3% response rate (Table 3). The questionnaire comprised five sections matching the research objectives and used a five-point Likert scale (1 = strongly disagree / very inadequate to 5 = strongly agree / very adequate). Data were analysed in SPSS version 25 using means, standard deviations and rankings, with a one-sample t-test performed on the highest-ranked success factor. In interpreting the results, the scale mid-point of 3.0 is used as the reference for adequacy or agreement.

Table 3: Distribution of questionnaires across the four buildings

Building / category	Administered	Returned	Response rate
NNPC Towers	30	22	73.3%
BOI Tower II	30	21	70.0%
World Trade Center	30	20	66.7%
Federal Ministry of Finance HQ	30	19	63.3%
Total	120	82	68.3%

Source: Authors' fieldwork (2025).

4.0 Results

4.1 Knowledge of Green Architecture Strategies

Table 4 and Figure 3 report professionals' awareness of the 23 strategies. Double or triple glazing ranked highest (Mean = 3.52, SD = 0.91), followed by fixed external shading devices (Mean = 3.41) and building form and orientation (Mean = 3.28) — the envelope, shading and orientation measures that are most established in practice. Awareness fell steadily through the more advanced strategies, with climate-responsive parametric design (1.94), chilled beams and ceilings (1.87) and ground-source heat pumps (1.79) least known. Notably, only the top six strategies exceeded the 3.0 mid-point, indicating that awareness is concentrated in a handful of conventional measures.

Table 4: Knowledge of green architecture strategies (N = 82)

S/N	Green architecture strategy	Mean	SD	Rank
1	Double or triple glazing	**3.52**	0.91	1st
2	Fixed external shading devices	**3.41**	0.88	2nd
3	Building form & orientation	**3.28**	0.97	3rd
4	Low-emissivity (low-E) coatings	**3.19**	0.94	4th
5	Natural ventilation	**3.12**	1.02	5th
6	High-efficiency HVAC systems	**3.05**	0.96	6th
7	Light-coloured or reflective facades	**2.98**	1.01	7th
8	Insulated spandrel panels	**2.89**	0.99	8th
9	Cool roofs	**2.81**	1.05	9th

S/N	Green architecture strategy	Mean	SD	Rank
10	Mixed-mode ventilation	**2.74**	1.03	10th
11	Ventilated or double-skin facades (DSF)	**2.67**	1.08	11th
12	Thermal breaks in curtain walls	**2.59**	1.01	12th
13	Green roofs & sky terraces	**2.52**	1.09	13th
14	Adaptive / responsive shading	**2.45**	1.04	14th
15	Building performance simulation (BPS)	**2.38**	1.07	15th
16	Night-purge ventilation	**2.31**	1.02	16th
17	Building-integrated photovoltaics (BIPV)	**2.24**	1.11	17th
18	Dynamic or smart glazing	**2.17**	1.06	18th
19	Displacement ventilation	**2.09**	0.98	19th
20	Active dynamic facades	**2.02**	1.03	20th
21	Climate-responsive parametric design	**1.94**	1.01	21st
22	Chilled beams / ceilings	**1.87**	0.97	22nd
23	Ground-source heat pumps	**1.79**	0.95	23rd

Source: Authors' analysis, SPSS v25 (2025).

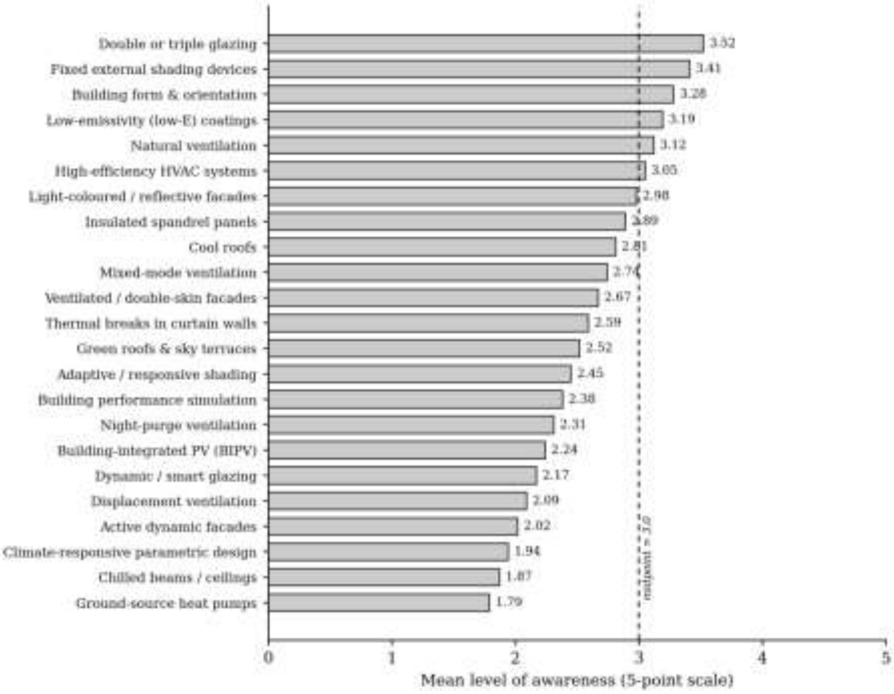

Figure 3: Mean level of professionals' awareness of the 23 strategies (dashed line = 3.0 mid-point)
Source: Authors' analysis (2025).

4.2 Current Level of Integration

Table 5 reports the perceived level of integration. Building form and orientation ranked highest (Mean = 3.18), followed by fixed external shading devices (Mean = 3.05) and double or triple glazing (Mean = 2.97); advanced strategies such as double-skin facades, dynamic facades and ground-source heat pumps recorded the lowest. The decisive finding, shown in Figure 4, is that integration lags awareness for every single strategy without exception: even the best-known measures are applied less than they are understood, and only two strategies reach the 3.0 mid-point in practice at all. The gap is a gap of application, not of awareness — a pattern that directs attention to the barriers examined next.

Table 5: Level of integration of green architecture strategies (N = 82)

S/N	Green architecture strategy	Mean	SD	Rank
1	Building form & orientation	**3.18**	0.93	1st
2	Fixed external shading devices	**3.05**	0.89	2nd
3	Double or triple glazing	**2.97**	0.96	3rd
4	High-efficiency HVAC systems	**2.84**	0.98	4th
5	Natural ventilation	**2.71**	1.04	5th
6	Low-emissivity (low-E) coatings	**2.63**	0.97	6th
7	Light-coloured or reflective facades	**2.55**	1.01	7th
8	Cool roofs	**2.42**	1.06	8th
9	Insulated spandrel panels	**2.35**	0.99	9th
10	Mixed-mode ventilation	**2.28**	1.03	10th
11	Thermal breaks in curtain walls	**2.19**	1.02	11th
12	Green roofs & sky terraces	**2.11**	1.08	12th
13	Ventilated or double-skin facades (DSF)	**2.04**	1.05	13th
14	Adaptive / responsive shading	**1.97**	1.01	14th
15	Building performance simulation (BPS)	**1.89**	1.04	15th
16	Night-purge ventilation	**1.82**	0.98	16th
17	Building-integrated photovoltaics (BIPV)	**1.75**	1.07	17th
18	Displacement ventilation	**1.68**	0.96	18th
19	Dynamic or smart glazing	**1.61**	0.99	19th
20	Active dynamic facades	**1.54**	1.02	20th
21	Climate-responsive parametric design	**1.47**	0.94	21st
22	Chilled beams / ceilings	**1.41**	0.91	22nd
23	Ground-source heat pumps	**1.35**	0.89	23rd

Source: Authors' analysis, SPSS v25 (2025).

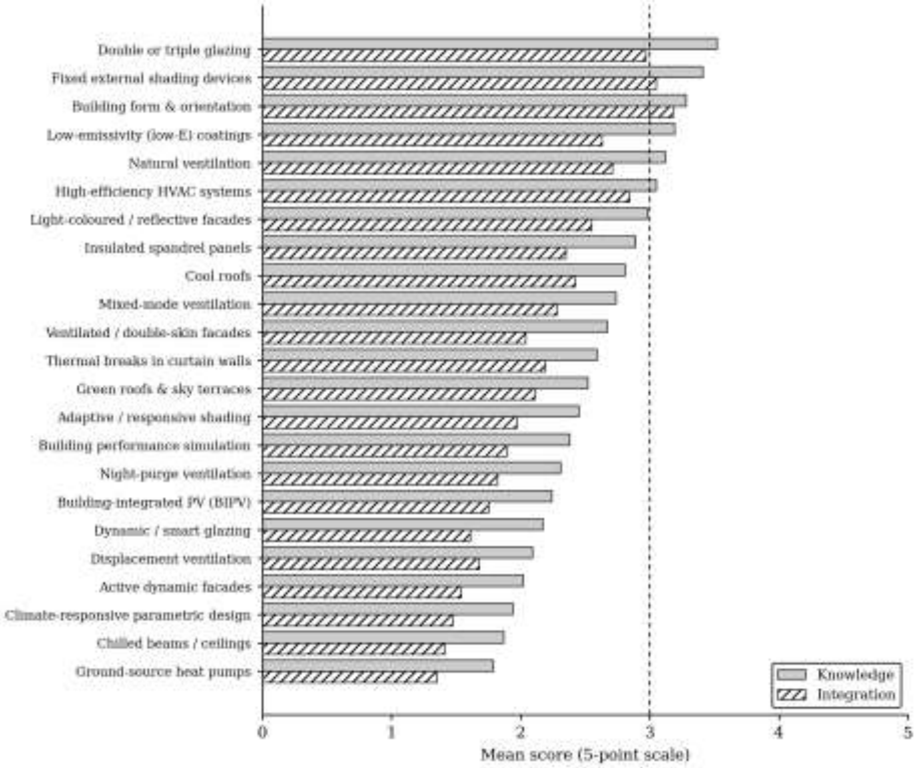

Figure 4: Knowledge (solid) versus integration (hatched) for each strategy; integration falls below awareness across the board
Source: Authors' analysis (2025).

4.3 Observed Applications in the Four Buildings

Field observation of the four buildings corroborated the survey (Table 6). The NNPC Towers present extensive curtain-wall glazing with limited shading and a predominantly east–west orientation that exposes the long facades to intense solar gain. BOI Tower II combines tinted glazing with intermittent horizontal shading on the southern elevation and some podium-level greenery — marginally better, though its window-to-wall ratio remains high. The World Trade Center is a fully glazed curtain-wall tower whose principal solar control is internal blinds, with form and orientation driven by appearance. The Federal Ministry of Finance Headquarters shows partial use of deep overhangs and recessed windows on some elevations, but its large eastern and western glazed areas remain unshaded and greenery is absent
.

Table 6: Observed passive and green features of the four case-study buildings

Building	Glazing / facade	External shading	Cooling & ventilation
NNPC Towers	Extensive curtain-wall glazing	Limited; long E–W facades exposed	Mechanical-dominated; minimal natural ventilation
BOI Tower II	Tinted glazing; high window-to-wall ratio	Intermittent horizontal devices (south); podium greenery	Mechanical, marginally better
World Trade Center	Fully glazed curtain wall	Minimal — internal blinds only	Mechanical-dominated; form favours aesthetics

Building	Glazing / facade	External shading	Cooling & ventilation
Fed. Min. of Finance HQ	Large glazed areas; E/W largely unshaded	Partial deep overhangs and recessed windows	Mechanical; green roofs and greenery absent

Source: Authors' field observation (2025).

4.4 Barriers to Integration

Table 7 and Figure 5 report the 18 barriers assessed. High initial capital cost ranked highest (Mean = 3.61), followed by lack of demand or awareness (Mean = 3.42) and a focus on aesthetics over performance (Mean = 3.35). A fragmented industry structure (2.28), challenges of scale and height (2.35) and valuation difficulties (2.42) ranked lowest. The leading barriers are economic and cultural rather than technical, locating the obstacle in how buildings are financed and valued rather than in any shortage of available strategies.

Table 7: Barriers to the integration of green architecture strategies (N = 82)

S/N	Barrier	Mean	SD	Rank
1	High initial (capital) costs	**3.61**	1.05	1st
2	Lack of demand or awareness	**3.42**	1.01	2nd
3	Focus on aesthetics over performance	**3.35**	0.98	3rd
4	Outdated or inflexible building codes	**3.28**	1.03	4th
5	Lack of skilled professionals & trades	**3.21**	1.00	5th
6	Perceived risk & uncertainty	**3.14**	1.06	6th
7	Cost-benefit timeframe mismatch	**3.07**	0.97	7th
8	Conservative industry culture	**2.99**	1.02	8th
9	Increased design complexity	**2.92**	0.99	9th
10	Approval & permitting hurdles	**2.85**	1.04	10th
11	Lack of integration in design process	**2.78**	0.96	11th
12	Split-incentive / principal-agent problem	**2.71**	1.01	12th
13	Perceived higher maintenance	**2.64**	0.98	13th
14	Need for specialized knowledge	**2.57**	1.03	14th
15	Performance gap	**2.49**	0.95	15th
16	Valuation challenges	**2.42**	1.00	16th
17	Challenges of scale & height	**2.35**	0.97	17th
18	Fragmented industry structure	**2.28**	0.94	18th

Source: Authors' analysis, SPSS v25 (2025).

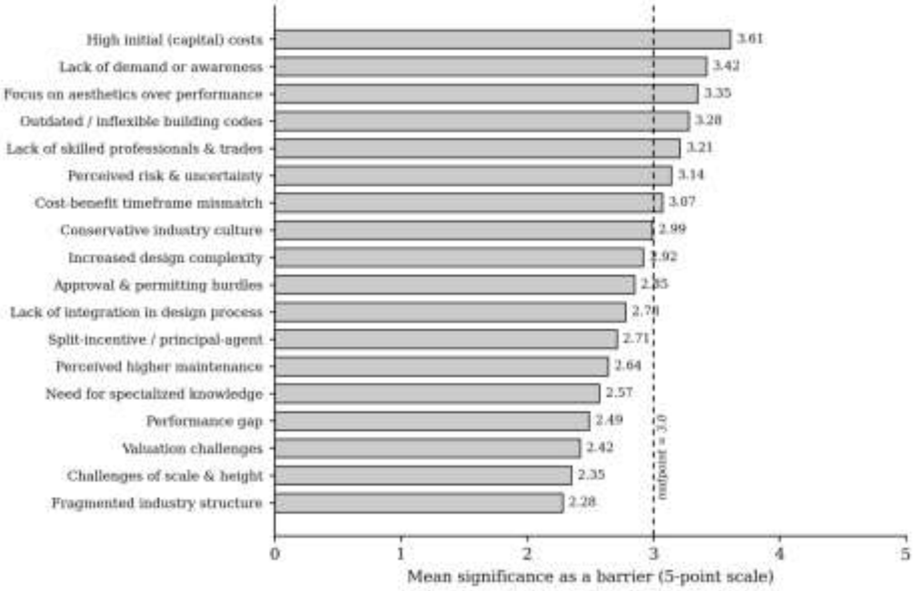

Figure 5: Mean significance of the 18 barriers (dashed line = 3.0 mid-point)
Source: Authors' analysis (2025).

4.5 Success Factors that Enhance Integration

Table 8 and Figure 6 report the 20 success factors. Stringent performance-based energy codes ranked highest (Mean = 3.68), followed by life-cycle cost analysis (Mean = 3.55) and education and cross-disciplinary training (Mean = 3.49). The pattern is coherent: enforceable codes, a life-cycle rather than first-cost view of value, and stronger professional capacity are seen as the levers most likely to move practice — each a direct answer to a leading barrier.

Table 8: Success factors that enhance integration (N = 82)

S/N	Success factor	Mean	SD	Rank
1	Stringent performance-based energy codes	**3.68**	0.91	1st
2	Life-cycle cost analysis	**3.55**	0.88	2nd
3	Education and cross-disciplinary training	**3.49**	0.94	3rd
4	Cost-effective high-performance materials	**3.42**	0.90	4th
5	Advanced building performance simulation	**3.36**	0.97	5th
6	Green financing / lower cost of capital	**3.29**	0.93	6th
7	Corporate ESG commitments & tenant demand	**3.22**	0.99	7th
8	Building information modelling (BIM)	**3.15**	0.95	8th
9	Success stories & living labs	**3.08**	1.01	9th
10	Industry certification as norms	**3.01**	0.96	10th
11	Specialist facade engineering	**2.94**	0.98	11th
12	Integrated project delivery	**2.87**	0.92	12th
13	Mandatory disclosure & benchmarking	**2.80**	1.00	13th
14	IoT & smart building management systems	**2.73**	0.97	14th
15	Fast-track permitting & density bonuses	**2.66**	1.03	15th

S/N	Success factor	Mean	SD	Rank
16	Post-occupancy evaluation	**2.59**	0.94	16th
17	Climate risk & resilience as drivers	**2.52**	0.99	17th
18	Performance-based procurement	**2.45**	0.91	18th
19	Robust financial valuation of green assets	**2.38**	0.96	19th
20	Carbon taxation & cap-and-trade systems	**2.31**	1.02	20th

Source: Authors' analysis, SPSS v25 (2025).

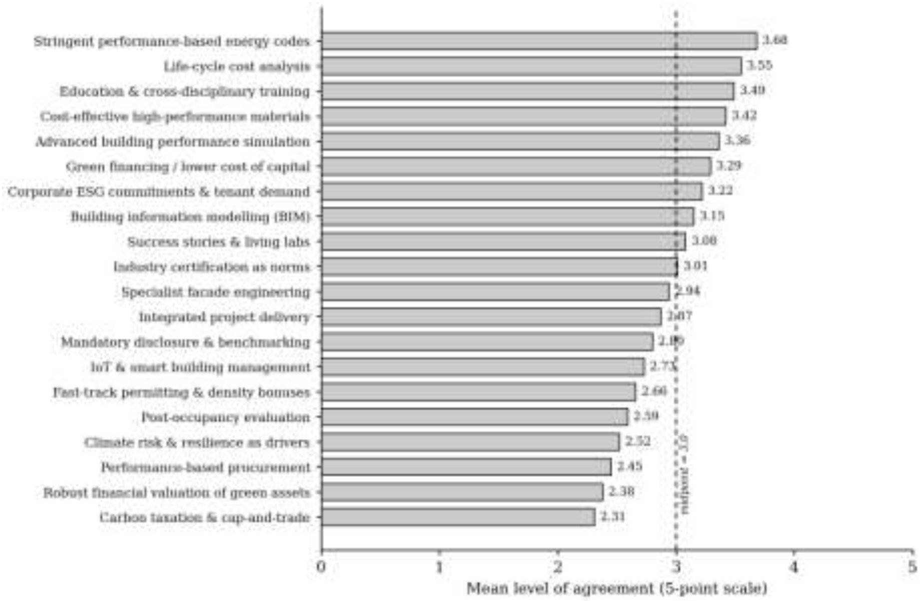

Figure 6: Mean level of agreement on the 20 success factors (dashed line = 3.0 mid-point)
Source: Authors' analysis (2025).

4.6 Inferential Statistics

A one-sample t-test examined whether the highest-ranked success factor, stringent performance-based energy codes, was rated significantly above the scale mid-point of 3.0. The result (Table 9) was significant — $t(81) = 6.77$, $p < 0.001$, mean = 3.68 — confirming that professionals regard enforceable, performance-based codes as a genuine enabler of green-architecture integration rather than a matter of indifference. Table 10 draws the four objectives together.

Table 9: One-sample t-test for the leading success factor (test value = 3.0)

Variable	N	Mean	SD	t	df	Sig. (2-tailed)
Stringent performance-based energy codes	82	3.68	0.91	6.77	81	< 0.001

Note: 95% CI [3.48, 3.88]; df = 81. Source: Authors' analysis (2025).

Table 10: Summary of the leading finding for each research objective

Research objective	Leading item	Mean	Key inference
Knowledge of strategies	Double or triple glazing	3.52	Awareness concentrates on envelope and glazing measures

Research objective	Leading item	Mean	Key inference
Extent of integration	Building form & orientation	3.18	Even the most-applied strategy barely reaches the midpoint
Barriers to integration	High initial (capital) costs	3.61	Cost is the dominant constraint on adoption
Success factors	Stringent performance-based energy codes	3.68	Enforceable codes are seen as the strongest enabler

Source: Authors' analysis (2025).

5.0 Discussion

The findings show that while professionals in Abuja possess moderate-to-high knowledge of the basic green strategies — glazing, external shading and orientation — actual integration remains limited, and lags awareness for every strategy assessed. This knowledge–application gap aligns with earlier observations that Nigerian high-rise buildings continue to rely on imported, climatically inappropriate templates (Okeke & Oyenuga, 2024; Mamman & Garba, 2021). Awareness, in other words, is not the binding constraint; the constraint lies downstream, in the economics and culture of how these buildings are procured.

Economic factors duly emerged as the dominant barrier, consistent with Bello and Ajayi (2023) and the wider literature on green-building adoption in developing countries. That the strongest-rated enablers are stringent performance-based codes, life-cycle cost analysis and professional education is telling: each directly answers a leading barrier — codes counter the first-cost bias, life-cycle analysis reframes value over time, and education addresses the shortage of skilled professionals. The photographic and observational evidence from the four buildings corroborates the quantitative results: extensive unshaded glazing, limited passive measures and heavy dependence on mechanical cooling remain the norm, with newer buildings such as BOI Tower II showing a marginal but still insufficient shift toward climate-responsive design.

6.0 Conclusion

This study evaluated the integration of green architecture design strategies for thermal performance in high-rise office buildings in Abuja. Professionals show a fair understanding of the essential strategies, but their actual application is moderate to low and consistently trails awareness. The principal obstacles are high initial cost, a demand-and-awareness deficit and a design culture that privileges appearance over performance, while enforceable performance-based codes, life-cycle costing and stronger professional capacity are identified as the key facilitators. On this basis the study recommends:

1. Introducing mandatory, context-adapted green building codes with clear enforcement mechanisms;
2. Providing targeted financial incentives — tax rebates and subsidies — for high-performance glazing, shading systems and passive design features;
3. Establishing continuous professional development focused on building-performance simulation and tropical design;
4. Incorporating clear, standardised maintenance schedules into project handover documentation; and
5. Promoting demonstration projects that showcase measurable reductions in cooling-energy demand. Further research should expand the sample to more buildings across Nigeria's different climatic zones and incorporate detailed energy-simulation modelling of the proposed interventions.

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