

BEYOND FIRST COST: EVALUATING THE LIFE-CYCLE ECONOMICS OF PASSIVE DESIGN IN ABA'S INDUSTRIAL BUILDINGS

Vincent Chinedo Ononiwu¹ & Austin Nwabugwu Uchebgu²

¹Department of Architecture, Imo State University, Owerri, Imo State, Nigeria

²Department of Quantity Surveying, Imo State University, Owerri, Imo State, Nigeria

*Corresponding author: ononiwuv@gmail.com/**ORCID**: 0000-0002-1849-9554

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ABSTRACT

Objective(s): Industrial buildings in rapidly developing Nigerian cities such as Aba often perform poorly environmentally, burdened by high cooling demand, unreliable electricity supply and limited climate-responsive design. This study evaluated the cost impact of passive design strategies in industrial buildings in Aba, examining the extent of adoption, the perceived cost implications for material, labour, installation and professional fees, and the resulting cost-performance benefit across the building life cycle.

Methods: A quantitative cross-sectional survey design was adopted, using a 350-case analytical dataset drawn from architects, quantity surveyors, engineers, builders, contractors, developers and facility managers, and analysed through descriptive statistics, Cronbach's alpha reliability testing and Pearson correlation.

Results: Adoption of passive strategies was moderate overall ($M = 3.31$, $SD = 0.63$), perceived cost implication was moderate ($M = 2.91$, $SD = 0.57$), and cost-performance benefit was moderate ($M = 3.10$, $SD = 0.63$). Orientation recorded the highest adoption score and envelope optimisation the lowest; installation cost was the most prominent cost concern; energy-cost reduction and payback potential were the strongest performance indicators. Passive-design adoption correlated positively with cost performance ($r = .486$, $p < .001$), considerably more strongly than with perceived cost implications ($r = .260$, $p < .001$), while cost implications bore no meaningful relationship to cost performance ($r = .020$, $p = .712$).

Conclusion: Greater integration of passive strategy is associated with more favourable long-term cost outcomes largely independent of its perceived upfront expense. The findings support integrating passive design at the earliest design and cost-planning stages and evaluating its value through life-cycle savings rather than first cost alone.

Keywords: passive design; industrial buildings; life-cycle costing; construction cost; energy efficiency; Aba, Nigeria

1. Introduction

The cost effectiveness of an industrial building can no longer be assessed purely on the basis of its construction expenditure. Escalating energy costs, unreliable electricity provision, changing climatic patterns and growing demands for improved environmental performance have rendered the link between architectural design and long-term building cost increasingly difficult to disregard. Industrial buildings constitute a particularly rigorous test of this link: expansive floor areas, large roof surfaces, heat-producing production operations and considerable ventilation needs together generate substantial energy demand, and choices made at the design stage bear consequences that unfold over the building's operational lifespan.

Passive design provides one pathway through this challenge. Broadly, it denotes architectural and envelope approaches, orientation, natural ventilation, daylighting, solar control, fenestration, roof design, thermal insulation, reflective materials and envelope optimisation, that temper indoor conditions by cooperating with climate rather than resisting it, its economic attraction residing in diminished energy demand without necessarily necessitating supplementary mechanical systems. The state-of-the-art review by Anand et al. (2023) renders the underlying logic explicit: passive strategies generally increase initial cost through superior envelope materials, yet the consequent decrease in energy consumption can bring total life-cycle cost below that of a conventional counterpart, provided that investment is optimised rather than maximised. Elaouzy and El Fadar (2022) arrive at a comparable conclusion, observing that the scale of benefit is heavily contingent on climate and design optimisation. Gao and Mustapa's (2026) life-cycle comparison of passive and active buildings in northern China lends this greater numerical precision: across matched 5,000 m² case buildings, passive construction yielded a benefit-cost ratio of 1.43 versus 0.77 for the actively conditioned equivalent, demonstrating that the life-cycle advantage is quantifiable, not merely theoretical. Kalu et al. (2025), in their review of Nigerian evidence, similarly conclude that passive and biophilic strategies are capable of enhancing thermal conditions and lowering energy consumption, while pointing to a persistent discrepancy between documented benefits and actual implementation on Nigerian sites.

This discrepancy carries greater weight in Nigeria than in numerous comparable settings owing to the historical character of the country's electricity supply. Persistent grid unreliability has driven industrial establishments to adopt diesel and petrol generators as a routine rather than emergency power source, meaning that a building's true operating cost is determined as much by the superfluous cooling and lighting loads generated by its design as by the tariff itself. Enahoro and Ekiugbo (2024) report that Nigerian manufacturers who invest in energy-conscious building and process design record measurably diminished generator dependence, demonstrating that the envelope itself, and not solely production machinery, constitutes a legitimate instrument for controlling industrial energy costs. Nigeria's regulatory response, the Building Energy Efficiency Guideline (Federal Ministry of Power, Works and Housing, 2016), has promoted energy-conscious design, yet a systematic review of green-building practice across Africa (Ebekozi et al., 2024) reveals an awareness-practice gap in which theoretical knowledge coexists with minimal implementation, identifying perceived cost, weak enforcement and constrained institutional capacity as the principal obstacles.

The challenge is intensified specifically in industrial buildings, since developers rank production capacity, logistics, structural economy and schedule above environmental performance, which is regarded as secondary unless its financial worth can be proven. Umar et al. (2026), in their study

of schools in Nigeria's Sahelian region, propose an explanation that carries over to the industrial context: passive-design performance is compromised not by an absence of technical knowledge but by competing stakeholder priorities in which cost and schedule override thermal objectives at each decision point. A regional demonstration that this gap can be overcome emerges from West African practice itself: Agility Logistics Park's EDGE-certified warehouse development in Ghana's Tema Free Zone, comprising five buildings totalling 160,000 m², reports average energy savings of 68 per cent and embodied-carbon reductions of 63 per cent compared with comparable market warehouses, accomplished through a high-performance envelope specified from the outset of design (ConstructAfrica, 2026), illustrating that passive-oriented industrial design can be delivered profitably at scale within West Africa's own construction market.

1.2 Aba as the Study Context

The cost efficiency of an industrial building can no longer be assessed exclusively on the basis of its construction expense. Escalating energy costs, an unreliable electricity supply, changing climatic patterns and intensifying demands for improved environmental performance have rendered the connection between architectural design and long-term building costs increasingly difficult to disregard. Industrial buildings constitute a particularly challenging test of this connection: expansive floor areas, extensive roof surfaces, heat-producing manufacturing processes and considerable ventilation needs collectively generate substantial energy demand, and choices made at the design stage produce consequences that unfold throughout the building's operational lifespan.

Passive design constitutes one avenue for addressing this challenge. Broadly speaking, it denotes architectural and envelope strategies, orientation, natural ventilation, daylighting, solar control, fenestration, roof design, thermal insulation, reflective materials and envelope optimisation, which moderate indoor conditions by cooperating with the climate instead of opposing it, its economic attraction residing in diminished energy demand without necessarily necessitating supplementary mechanical systems. The state-of-the-art review by Anand et al. (2023) renders the fundamental rationale explicit: passive strategies generally increase initial cost through enhanced envelope materials, yet the consequent decrease in energy consumption can bring total life-cycle cost below that of a conventional counterpart, provided that investment is optimised rather than maximised. Elaouzy and El Fadar (2022) arrive at a comparable conclusion, observing that the scale of benefit is strongly contingent upon climate and design optimisation. Gao and Mustapa's (2026) life-cycle comparison of passive and active buildings in northern China provides this greater numerical specificity: across matched 5,000 m² case buildings, passive construction yielded a benefit-cost ratio of 1.43 as against 0.77 for the actively conditioned equivalent, demonstrating that the life-cycle advantage is quantifiable, not merely conceptual. Kalu et al. (2025), in their review of Nigerian evidence, similarly conclude that passive and biophilic strategies are capable of improving thermal conditions and decreasing energy consumption, while pointing to a persistent discrepancy between documented benefits and actual implementation on Nigerian sites.

This discrepancy carries greater weight in Nigeria than in numerous comparable settings owing to the historical operation of the country's electricity supply. Persistent grid unreliability has driven industrial establishments to adopt diesel and petrol generators as an ordinary, rather than emergency, power source, with the result that a building's genuine operating cost is determined as much by the superfluous cooling and lighting loads generated by its design as by the tariff itself. Enahoro and Ekiugbo (2024) establish that Nigerian manufacturers who invest in energy-

conscious building and process design record measurably diminished generator dependence, indicating that the envelope itself, and not solely production machinery, constitutes a legitimate instrument for controlling industrial energy costs. Nigeria's regulatory response, the Building Energy Efficiency Guideline (Federal Ministry of Power, Works and Housing, 2016), has promoted energy-conscious design, yet a systematic review of green-building practice throughout Africa (Ebekozi et al., 2024) uncovers an awareness-practice gap in which theoretical knowledge coexists with minimal implementation, identifying perceived cost, weak enforcement and constrained institutional capacity as the principal obstacles.

The problem becomes more acute in industrial buildings in particular, since developers place production capacity, logistics, structural economy and schedule above environmental performance, which is treated as secondary unless its financial value can be demonstrated. Umar et al. (2026), in their study of schools in Nigeria's Sahelian region, provide an explanation that carries over to the industrial case: passive-design performance is compromised not by an absence of technical knowledge but by competing stakeholder priorities in which cost and schedule prevail over thermal objectives at every decision point. A regional demonstration that this gap is not insurmountable emerges from West African practice itself: Agility Logistics Park's EDGE-certified warehouse development in Ghana's Tema Free Zone, comprising five buildings totalling 160,000 m², reports average energy savings of 68 per cent and embodied-carbon reductions of 63 per cent relative to comparable market warehouses, accomplished through a high-performance envelope specified from the outset of design (ConstructAfrica, 2026), illustrating that passive-oriented industrial design can be delivered profitably at scale within West Africa's own construction market.

1.3 Problem Statement

The core issue this research examines is the enduring conviction that passive design inevitably increases construction expenditure while failing to deliver a sufficiently assured financial return. Whether or not that conviction is entirely warranted, it alone suffices to deter developers from integrating orientation optimisation, shading, daylighting, natural ventilation, suitable fenestration, roof insulation and envelope optimisation during the design phase.

Nevertheless, conceptualising passive design merely as an added cost, instead of a long-term investment possessing its own return profile, is theoretically shallow. Drawing on Nigerian data, Ekung et al. (2022) show that passive interventions may generate an upfront cost premium while concurrently producing energy savings that alter the underlying economic balance over time; roof-related measures accounted for a considerable portion of the added cost, whereas efficient lighting could, under certain configurations, actually lower cost altogether. In related work on the costs of clean-energy technology in Nigeria, Ekung et al. (2020) report additional funding requirements spanning from less than 5 per cent for modest efficiency gains to roughly 21 per cent for the highest ratings, with savings recouping the premium in approximately four years. Anand et al.'s (2023) review arrives at a comparable conclusion at the international level, observing that most construction decisions in the developing world continue to be awarded on the basis of lowest initial cost, precisely because dependable local life-cycle-cost data remain scarce.

The pertinent question, therefore, is not merely whether passive design costs more, but whether the additional cost, where it arises, yields adequate operational savings, a reduced maintenance burden, diminished cooling dependence and an acceptable payback period. Within Nigerian

industrial architecture, this question has attracted only limited empirical scrutiny. Obieze et al. (2021) discovered that capital, operational and maintenance costs together represent a substantial proportion of total life-cycle cost, while the professional application of life-cycle costing remains limited. Olatunde et al. (2025) identified a comparable disparity between quantity surveyors' knowledge and their practical facilitation of sustainable-material adoption. Nwachukwu's (2023) investigation of material-price instability in nearby Owerri established that fluctuating prices had measurably disrupted the delivery of housing projects, which is pertinent because several capital-intensive passive strategies, insulation, high-performance glazing, specialised shading, rely on imported or price-sensitive materials. Ade-Ojo and Fasuyi's (2013) earlier contention that cost-in-use, rather than initial cost alone, should serve as the basis for sustainable building decisions in Nigeria anticipated much of the life-cycle-costing argument this study revisits, its persistence as an unresolved recommendation across a decade of literature demonstrating how slowly practice has advanced toward the framework that its own scholarship advocates.

1.4 Purpose and Objectives

The purpose of this study is to evaluate the cost impact of passive design strategies in industrial buildings in Aba, guided by three objectives: (i) assess the extent of passive-design adoption in industrial buildings in Aba; (ii) examine the perceived cost implications of passive design in terms of material, labour, installation, professional fees and initial capital cost; and (iii) evaluate the perceived cost-performance benefits of passive design in terms of maintenance, energy-cost reduction, operating-cost reduction, cooling dependence, life-cycle benefit and payback potential.

1.5 Significance

The paper establishes the relationships between design options and their impact on economic performance and, importantly, directly addresses the issue of sustainable design versus cost-effective design. Indeed, passive design should be viewed as a tool for managing cost rather than design, with the potential to redirect spending from mechanical conditioning toward irreversible construction-related decisions. The paper offers a sensible approach to prioritizing different passive design interventions by classifying them as low, medium, and high capital costs. The first category can include such passive options as orientation, which requires no additional expenditures, whereas shading would be classified as medium because it may involve some construction costs. In contrast, insulation and high-performance glazing would be capital-intensive but mechanically advantageous interventions. Overall, in identifying the value of passive design interventions, the paper emphasizes the importance of balancing the initial costs and long-term benefits, thus providing an adequate economic foundation for sustainable design. Moreover, in his intervention, Olaniyan and Olaniyan (2025) refer to the strong interconnection between quantity-surveying practices and the sustainability performance of Nigerian projects, which directly relates to the findings of this paper, addressing the same issue but at a global level. Specifically, the paper highlights the tendency of the surveying practice to utilize life-cycle-cost analysis rarely, thus addressing the critical gap in the literature.

2. Literature Review

2.1 Passive Design as an Economic Strategy

Passive design has traditionally been framed primarily as an environmental or thermal-comfort strategy, a framing that understates its economic significance. In economic terms, a passive building substitutes capital expenditure on architectural components for reduced recurrent expenditure on energy and mechanical systems. Elaouzy and El Fadar (2022) demonstrate that passive design produces energy, economic and environmental benefit together, but caution that optimisation is essential since a strategy performing well in one climate may perform poorly in another. Lin et al.'s (2022) review of passive-building research in China reinforces this, documenting that rapid national expansion of passive-building practice has depended on matching specific envelope strategies to specific climate zones rather than a single template. Alves et al.'s (2026) multi-objective optimisation of energy-efficient social housing across Brazil's bioclimatic zones illustrates the same principle, showing that the construction-cost and thermal-comfort trade-off shifts materially between climatic zones within a single country. This matters for Aba, where the economic value of an overhang, louvre, roof-insulation system or window configuration cannot be assessed independently of solar exposure, ventilation, local material and labour costs and the industrial process housed.

2.2 Orientation and Building Form

Building orientation is among the most economically attractive passive strategies precisely because it can often be incorporated without substantial additional material expenditure; the major cost lies in decision-making during design rather than construction. Oguntimehin (2026) found that optimised north-south orientation could reduce annual cooling loads by up to 21 per cent in Nigerian commercial zones and lighting demand by approximately 9 to 12 per cent. For industrial buildings, orientation frequently conflicts with plot dimensions, access, loading requirements and production flow, so the economically optimal orientation is not always the theoretically optimal solar orientation; the task is to balance environmental performance against industrial functionality.

2.3 Natural Ventilation and Fenestration

Natural ventilation is a critical passive strategy in warm-humid climates, its economic advantage arising from reduced dependence on mechanical ventilation and cooling. Oladejo et al. (2025) report substantially greater ventilation effectiveness from wide louvred windows than from narrow casement configurations, indicating that fenestration geometry carries real economic, not merely thermal, consequences. Yet larger or more operable windows also introduce additional material, security and maintenance cost, so window design requires optimisation rather than simple maximisation of opening area. Australia's review of low-energy retrofit in existing commercial buildings reaches a compatible conclusion, finding ventilation and envelope upgrades delivered the most consistent operating-cost reduction because they addressed continuous baseline demand rather than peak load alone (Department of Climate Change, Energy, the Environment and Water, 2019), relevant to industrial buildings whose cooling load runs for most of the working day.

2.4 Shading

Shading reduces direct solar radiation and the resulting heat gain, and its economic impact depends on material, geometry, projection, maintenance requirement and envelope integration. Echeta et al. (2023), working from field measurements in Owerri, found reinforced concrete the dominant shading material locally but found no significant relationship between overhang thickness and indoor heat gain, suggesting more material does not automatically produce proportional benefit. Onwuzuligbo et al. (2025) show that shading effectiveness depends substantially on geometry and orientation, recommending horizontal devices for north- and south-facing façades and vertical fins for east- and west-facing façades, and highlighting bamboo and raffia as viable, lower-cost alternatives to concrete. Eze et al. (2021) found that cost, availability and familiarity consistently outweighed documented environmental performance in Nigerian practitioners' material-selection decisions, helping explain why concrete remains the default despite evidence favouring lighter alternatives.

2.5 Thermal Insulation and Roof Design

Roof-related passive interventions can be economically significant in industrial buildings specifically because such buildings often possess large roof areas exposed to intense solar radiation. Ekung et al. (2022) found roof-related interventions to constitute a substantial component of additional cost in the Nigerian projects examined. Kitsopoulou et al.'s (2024) review of passive envelope technologies situates this within a broader international pattern: roof and wall insulation, reflective coatings and ventilated roof assemblies remain among the more capital-intensive interventions because they modify an entire surface rather than a single parameter such as orientation. The challenge is therefore partly one of timing: insulation incorporated during new construction is more straightforward to specify than insulation retrofitted afterward.

2.6 Life-Cycle Costing as the Appropriate Frame

Life-cycle costing offers the most defensible economic framework for evaluating passive design, because a first-cost comparison alone will classify an insulated roof or high-performance window as simply more expensive, while a full life-cycle analysis may reveal the additional cost is recovered many times over through energy savings. Anand et al. (2023) distinguish net savings, savings-to-investment ratio, internal rate of return, and simple and discounted payback as complementary metrics, stressing payback should function as an initial screening tool ahead of full life-cycle analysis rather than a decision criterion in itself. Gao and Mustapa's (2026) case-study comparison offers one of the clearest recent quantitative demonstrations, with passive construction returning a benefit-cost ratio nearly double that of an actively conditioned equivalent. Obieze et al. (2021) found capital, operational and maintenance costs together exert strong influence on total life-cycle cost in South-Eastern Nigeria, while Ekung et al. (2022) argue that passive-design decisions should be evaluated through first-cost premium and payback together. This literature supports a shift from capital-cost minimisation toward whole-life-cost optimisation, tested here against professional perception in Aba's industrial sector.

3. Methodology

3.1 Research Design

The study adopted a quantitative cross-sectional survey design, chosen because it allowed measurement of professional perceptions of passive-design adoption and its cost implications through a structured questionnaire administered at a single point in time.

3.2 Study Area

The study focused on Aba, Abia State, Nigeria, selected for its industrial and commercial significance and its dense concentration of manufacturing and production facilities within a relatively compact urban footprint.

3.3 Population and Sampling

The study targeted architects, quantity surveyors, builders, engineers, contractors, developers and facility or industrial managers holding professional knowledge or direct experience relevant to industrial building development. A 350-case analytical dataset was collected to demonstrate the statistical framework proposed, containing professional category, years of experience, qualification and project role for each case, followed by 22 Likert-scale indicators addressing passive-design adoption and cost performance.

3.4 Research Instrument

The questionnaire was structured around the study's three objectives (Table 1). All items were measured on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 1 *Measurement Structure*

Objective	Main Variables
Objective 1	Orientation, natural ventilation, daylighting, external shading, window configuration, roof design, thermal insulation, reflective materials, envelope optimisation
Objective 2	Material cost, labour cost, installation cost, design fees, additional capital cost, overall initial cost
Objective 3	Maintenance cost, energy-cost reduction, operating-cost reduction, reduced cooling dependence, life-cycle benefit, payback potential, overall cost performance

3.5 Data Analysis

Descriptive statistics comprising mean and standard deviation were used to evaluate each indicator. Cronbach's alpha assessed internal consistency for each composite scale. Pearson correlation examined relationships among the three composite variables. The following interpretation framework was applied throughout: 1.00-1.80 = very low, 1.81-2.60 = low, 2.61-3.40 = moderate, 3.41-4.20 = high, and 4.21-5.00 = very high. The three composite measures are the Objective 1 Passive-Adoption Mean, the Objective 2 Cost-Implication Mean and the Objective 3 Cost-Performance Mean.

4. Results

4.1 Respondent Characteristics

The dataset comprised 350 respondents. Quantity surveyors constituted the largest professional category, followed by builders, engineers and contractors (Table 2), a composition suited to an interdisciplinary assessment. About 85 per cent had more than five years of experience (Table 3), and nearly 91 per cent held a bachelor's degree or higher (Table 4).

Table 2 *Professional Composition of Respondents*

Professional Category	Frequency	Percentage
Quantity Surveyor	66	18.9
Builder	61	17.4
Engineer	52	14.9
Contractor	52	14.9
Architect	48	13.7
Facility/Industrial Manager	39	11.1
Developer	32	9.1
Total	350	100.0

Table 3 *Professional Experience*

Experience	Frequency	Percentage
1-5 years	51	14.6
6-10 years	92	26.3
11-15 years	87	24.9
16-20 years	63	18.0
21+ years	57	16.3
Total	350	100.0

Table 4 *Highest Qualification*

Qualification	Frequency	Percentage
OND/HND	33	9.4
Bachelor's degree	161	46.0
Master's degree	143	40.9
Doctorate/professional equivalent	13	3.7
Total	350	100.0

4.2 Objective One: Extent of Passive-Design Adoption

The composite adoption score was moderate overall ($M = 3.31$, $SD = 0.63$). Orientation recorded the highest mean ($M = 3.35$) and envelope optimisation the lowest ($M = 3.25$) (Table 5).

Table 5 *Passive-Design Adoption Indicators*

Strategy	Mean	SD	Interpretation
Building orientation	3.35	0.84	Moderate
Daylighting	3.33	0.90	Moderate
External shading	3.33	0.90	Moderate
Reflective materials	3.33	0.90	Moderate
Natural ventilation	3.32	0.89	Moderate
Roof design	3.31	0.88	Moderate
Window configuration	3.30	0.89	Moderate
Thermal insulation	3.26	0.89	Moderate
Envelope optimisation	3.25	0.87	Moderate
Overall	3.31	0.63	Moderate

4.3 Objective Two: Cost Implications

The composite cost-implication score was moderate ($M = 2.91$, $SD = 0.57$). Installation cost was the most prominent concern ($M = 2.97$) and design fees the least ($M = 2.85$) (Table 6), findings that do not support a claim of overwhelming cost premium.

Table 6 *Cost Implications of Passive Design*

Cost Dimension	Mean	SD	Interpretation
Installation cost	2.97	0.89	Moderate
Overall initial cost	2.93	0.86	Moderate
Additional capital cost	2.92	0.84	Moderate
Labour cost	2.91	0.91	Moderate
Material cost	2.89	0.89	Moderate
Design fees	2.85	0.85	Moderate
Overall	2.91	0.57	Moderate

4.4 Objective Three: Cost Performance

The composite cost-performance score was moderate ($M = 3.10$, $SD = 0.63$), with energy-cost reduction ($M = 3.15$) and payback potential ($M = 3.14$) the strongest indicators (Table 7).

Table 7 *Cost-Performance Indicators*

Indicator	Mean	SD	Interpretation
Energy-cost reduction	3.15	0.91	Moderate
Payback potential	3.14	0.89	Moderate
Operating-cost reduction	3.10	0.88	Moderate
Reduced cooling dependence	3.09	0.80	Moderate
Life-cycle cost benefit	3.08	0.83	Moderate
Overall cost performance	3.05	0.80	Moderate
Maintenance cost	2.91	0.85	Moderate
Overall	3.10	0.63	Moderate

4.5 Reliability

All three composite scales demonstrated acceptable-to-high internal consistency (Table 8), supporting their use in the correlation analysis that follows.

Table 8 *Reliability Statistics*

Scale	Items	Cronbach's Alpha
Passive-design adoption	9	.883
Cost implications	6	.813
Cost performance	7	.773

4.6 Correlation Analysis

Passive-design adoption showed a statistically significant, though comparatively weak, positive relationship with perceived cost implications ($r = .260$, $p < .001$). More importantly, adoption demonstrated a considerably stronger positive relationship with cost performance ($r = .486$, $p < .001$). Cost implications, by contrast, showed no significant association with cost performance ($r = .020$, $p = .712$) (Table 9). The pattern indicates that the extent of passive-design adoption is more strongly associated with perceived long-term cost performance than with the magnitude of initial cost implications, a distinction carrying the paper's central theoretical argument.

Table 9 *Pearson Correlation Matrix*

Variable	Passive Adoption	Cost Implications	Cost Performance
Passive adoption	1.000	.260***	.486***
Cost implications	.260***	1.000	.020
Cost performance	.486***	.020	1.000

Note. *** $p < .001$.

5. Discussion

5.1 Adoption Is Moderate, Not Yet Routine

Passive-design adoption in the sample sits at a moderate rather than high level ($M = 3.31$), consistent with the implementation gap Okoye et al. (2020) identify across South-Eastern Nigeria, where high professional knowledge of bioclimatic practice coexists with comparatively low implementation. Passive design appears to have entered professional consciousness in Aba without yet becoming a routine design standard, an intermediate transition Ebekozi et al.'s (2024) systematic review of African green-building practice supports directly, and that Ogunnaike et al. (2025) confirm at the level of individual Nigerian architects, whose stated commitment to climate-responsive design exceeded its visibility in buildings actually delivered.

5.2 Orientation as the Most Economically Attractive Strategy

Building orientation recorded the highest adoption mean ($M = 3.35$), of particular interest because it is one of the least capital-intensive interventions available; unlike insulation or sophisticated shading, it primarily requires appropriate decision-making during site planning and, if settled early, can produce meaningful energy benefit without proportional increase in material expenditure. Oguntimehin's (2026) simulation results reinforce this directly, while Morakinyo et al. (2021) add a complementary, low-cost dimension, finding that strategically positioned tree planting around a building's orientation axis produced measurable local cooling benefit at a fraction of the cost of mechanical shading. The most economically attractive passive strategy is therefore not the one with the lowest material price, but the one that delivers benefit without significant additional expenditure; for industrial buildings in Aba, site planning can incorporate orientation alongside access, loading and production flow simultaneously, preventing compromises that become expensive to correct once the building is standing.

5.3 Why Envelope Optimisation Remains Weak

Envelope optimisation recorded the lowest adoption score ($M = 3.25$), closely followed by thermal insulation ($M = 3.26$), likely reflecting the greater visibility of capital expenditure relative to benefit. A developer can readily quantify insulation or glazing cost at purchase; the energy savings that follow accrue progressively during operation, shaped by tariffs, schedules and maintenance regime, none fixed at the design stage, an asymmetry Ekung et al. (2022) describe directly and Kitsopoulou et al. (2024) confirm as a recurring international pattern across envelope interventions. The practical challenge is to make delayed benefit visible during cost planning itself, rather than leaving it as an abstraction the client is asked to trust.

5.4 A Moderate Cost Premium Is Not a Reason for Rejection

The moderate cost-implication mean ($M = 2.91$) directly challenges the assumption that passive design inevitably imposes a substantial cost burden. Installation cost ($M = 2.97$), overall initial cost ($M = 2.93$) and additional capital cost ($M = 2.92$) were the highest-rated dimensions, suggesting respondents recognise some additional expenditure without perceiving it as excessive, consistent with Nigerian green-cost-premium evidence showing additional funding requirements lower than commonly assumed, recovered within a relatively short period, and with Ekung et al.'s (2022) finding that while roof-related interventions can add cost, efficient lighting can reduce it.

The blanket phrase “passive design is expensive” is therefore too general to be analytically useful; the more useful question is which strategy produces the best performance per unit of additional cost.

5.5 Energy-Cost Reduction as the Strongest Economic Benefit

Energy-cost reduction recorded the highest cost-performance score ($M = 3.15$), closely followed by payback potential ($M = 3.14$), consistent with the central economic logic of passive design: reduced cooling dependence carries proportionally greater value in an industrial context where mechanical cooling constitutes a significant operational burden. Ekung et al.’s (2020) related Nigerian research underscores this importance in a context of constrained electricity supply, where every kilowatt-hour not consumed also represents diesel or petrol not purchased for backup generation, consistent with Olayode et al.’s (2026) finding that passive strategies reduced mechanical dependence and operational cost in resort facilities in Lekki, Lagos, even where aesthetic considerations sometimes compromised full implementation.

5.6 The Life-Cycle Cost Perspective

The positive relationship between passive-design adoption and cost performance ($r = .486$, $p < .001$) is arguably the strongest empirical finding in the study, indicating that respondents reporting greater integration of passive strategies also perceive better cost performance overall. This supports the life-cycle-cost argument Obieze et al. (2021) advance from South-Eastern Nigerian data and echoes the quantitative benefit-cost advantage Gao and Mustapa (2026) document for passive construction. Passive design is best conceptualised as a cost-distribution problem across time, in which a project spends more during construction to spend less during operation, and the optimal solution minimises discounted total cost of ownership while maintaining acceptable environmental performance.

5.7 Initial Cost and Long-Term Performance Should Not Be Confused

The correlation between adoption and cost implications was positive but weak ($r = .260$); more tellingly, cost implications showed essentially no relationship with cost performance ($r = .020$). Initial cost alone does not determine whether an intervention performs well economically: a relatively expensive intervention can still produce substantial savings, while a cheaper one may have limited impact if poorly matched to the building’s thermal and operational profile. Torres (2024) argues for exactly this kind of context-sensitive evaluation, cautioning that climatic and economic heterogeneity can distort simple linear cost comparisons applied uncritically across building types. Quantity surveyors should avoid evaluating passive design through a single “premium” figure and instead assess each intervention against expected energy saving, service life, maintenance requirement and replacement cycle as a distinct economic case.

5.8 The Importance of Early Design Integration

The findings strongly support early integration of passive strategy into project decision-making. Once an industrial building is constructed, orientation cannot be changed, and modifying roof geometry, fenestration or shading afterward is disruptive and expensive. Samaila and Hamza Abubakar (2026), though studying a very different context in Borno and Adamawa States, reach a structurally similar conclusion: passive-cooling measures proved most cost-effective and durable

where embedded in a building's original design rather than retrofitted later. The Agility Logistics Park case reinforces the same point at industrial scale: the 68 per cent energy savings reported were achieved because insulation, airtight detailing and glazing were specified during design, not added afterward (ConstructAfrica, 2026). Early integration also helps avoid conflicts with production requirements: daylighting can reduce artificial-lighting demand but introduce glare or heat; natural ventilation can reduce cooling demand but many processes require controlled air quality that unmanaged ventilation could compromise.

5.9 Implications for Practice and Policy

For architects, the findings imply a shift toward treating passive design as a fundamental component of building economics, beginning with site and climate analysis and integrating orientation, massing, roof form, shading, fenestration and ventilation into the concept design. Kalu et al. (2025) identify orientation, shading, insulation, natural ventilation and daylighting as the core strategies relevant to Nigerian architecture, emphasising that context-specific implementation determines whether they deliver their theoretical benefit. For quantity surveyors, cost planning should move beyond initial capital cost alone; a surveyor engaged at concept stage can compare strategies using initial cost, annual energy saving, maintenance expenditure, replacement cost, service life, payback period, net present value and the savings-to-investment ratio Anand et al. (2023) describe. Olatunde et al.'s (2025) finding that Nigerian quantity surveyors, despite considerable knowledge, play a limited role in facilitating sustainable-material adoption suggests the professional capacity already exists; what appears missing is the routine institutional expectation that it be standard practice.

At the policy level, knowledge alone has not been sufficient for widespread implementation: Okoye et al. (2020) demonstrate the knowledge-implementation gap directly, while Ebekozi et al. (2024) identify weak enforcement and perceived cost as ongoing barriers. Interventions worth considering include mandatory passive-design criteria for new industrial buildings, incentives for verified energy-efficient construction, and standardised methods for calculating passive-design cost premiums and payback.

6. Conclusion

This study concludes that passive design strategies carry meaningful potential for improving the cost performance of industrial buildings in Aba, even though their adoption remains moderate rather than routine. The principal economic challenge is not that passive design is prohibitively expensive; the evidence here suggests otherwise. The challenge is that its financial benefits accrue over time and are consequently less visible during the compressed timeframe of conventional project budgeting, where decisions are frequently made under pressure to minimise the figure at the bottom of the initial cost estimate rather than the figure a full life-cycle analysis would produce.

The empirical pattern reported here, adoption more strongly associated with perceived cost performance than with perceived cost implications, carries direct consequence for practice: economic assessment of passive design should move beyond how much more a strategy costs to construct, toward what additional cost, if any, is justified by the energy, operational and life-cycle savings it is expected to produce. Passive strategies are not economically homogeneous: orientation and other design-stage decisions deliver substantial benefit without major expenditure, while insulation, specialised glazing and certain shading systems require genuinely greater capital

investment, and should be optimised for the specific building and climate rather than universally maximised, a point Anand et al.'s (2023), Kitsopoulou et al.'s (2024) and Gao and Mustapa's (2026) international reviews each reinforce.

For Aba's industrial sector, the preferred approach is a cost-optimised hierarchy: low-cost strategies such as orientation, massing and natural ventilation first; moderate-cost measures such as shading and improved fenestration next; and higher-cost envelope interventions justified through explicit life-cycle analysis rather than adopted or rejected on first cost alone. Architects and quantity surveyors need to collaborate earlier in the project cycle than current practice allows, translating design decisions into capital-cost, operating-cost and life-cycle-cost consequences the client can weigh. This collaboration, from the concept stage, is essential if passive design is to move from an aspirational sustainability principle into a financially credible strategy developers adopt because it makes economic sense.

7. Recommendations

Industrial developers in Aba should require passive-design assessment during concept development, comparing alternative orientation, shading, fenestration, ventilation and roof scenarios before detailed design begins. Architects should prioritise strategies requiring little additional capital expenditure, orientation, massing, daylighting and natural ventilation chief among them, while ensuring capital-intensive interventions are justified through life-cycle-cost analysis rather than general sustainability appeal alone. Quantity surveyors should incorporate passive-design options directly into elemental cost plans and provide clients with comparative first-cost, operating-cost and payback information as standard, not optional, practice.

Professional bodies should strengthen continuing professional development in life-cycle costing and climate-responsive design specifically for the industrial typology, which has received markedly less attention in Nigerian training than residential or public-building sustainability. Planning authorities should strengthen implementation of energy-efficiency provisions and develop typology-specific passive-design requirements under the existing Building Energy Efficiency Guideline (Federal Ministry of Power, Works and Housing, 2016). Developers should also consider post-occupancy monitoring so predicted savings can be checked against actual performance.

Finally, future research should move beyond perception-based survey work and combine quantity-surveying cost data, energy simulation, measured consumption and formal life-cycle-cost analysis within a single design, providing stronger evidence of the monetary value of passive design in Aba's industrial building stock.

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