

Designing With Fabric Intelligence: An Interdisciplinary Architecture–Textile Framework for Low-Carbon and Inclusive Housing Delivery in Nigeria

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Abstract- Rapid urbanisation, escalating construction costs, and environmental pressures continue to constrain the delivery of affordable housing in Nigeria, necessitating innovative, low-carbon, and context-responsive solutions. This study investigates how “fabric intelligence,” derived from textile systems, can inform sustainable housing by integrating architectural design and textile entrepreneurship. A PRISMA-informed systematic review of Scopus and Web of Science databases identified 528 records (2016–2026), of which 58 peer-reviewed studies met the inclusion criteria. The methodology combines qualitative thematic synthesis with quantitative, correlation, and regression analyses to evaluate relationships among material innovation, textile-informed design, and system integration. Findings indicate that textile-informed strategies achieve embodied-carbon reductions of 18–50% (mean ≈34%) and thermal-comfort improvements averaging 3.1°C, while enhancing modularity, adaptability, and construction efficiency. The integration of indigenous textile systems further strengthens cultural relevance and supports inclusive economic participation through localised value chains. However, adoption remains constrained by regulatory limitations, technological gaps, and weak institutional coordination. The study advances an interdisciplinary Architecture–Textile Framework that positions fabric intelligence as an integrative mechanism linking environmental performance, adaptive design, and socio-economic systems. It concludes that textile-informed housing provides a scalable pathway for low-carbon, culturally responsive, and economically inclusive housing delivery in Nigeria and comparable developing contexts.

Index Terms- Fabric intelligence; Textile-informed architecture; Sustainable housing; Affordable housing systems; Nigeria

I. INTRODUCTION

Rapid urbanisation continues to exert significant pressure on housing systems globally, particularly in

developing regions where demand consistently outpaces supply (Zhang, 2016; Nwalusi et al., 2022; Deki et al., 2025). Sub-Saharan Africa, and Nigeria in particular, faces a persistent housing deficit driven by rapid population growth, rural–urban migration, and inadequate infrastructure provision. International projections further indicate sustained urban expansion, intensifying the urgency for scalable, affordable, and adaptable housing solutions (United Nations, 2019; UN-Habitat, 2020). In Nigeria, these challenges are compounded by escalating construction costs, heavy dependence on conventional materials, and limited innovation in housing delivery systems, resulting in affordability constraints and inflexible built environments (Jiboye et al., 2020; Olubi & Aseyan, 2022; Ogundipe et al., 2024; Vivian & Khaidzir, 2024; Enwin & Ikiriko, 2024; Garba et al., 2024; Alabi & Fapohunda, 2021). Beyond affordability concerns, environmental sustainability has emerged as a critical dimension of housing delivery. The construction sector remains a major contributor to global greenhouse gas emissions due to its reliance on energy-intensive materials such as cement and steel (Zhong et al., 2021; Gursel et al., 2023; Kane et al., 2025). International climate frameworks emphasise the urgent need to reduce embodied carbon and transition towards low-impact material systems (IPCC, 2022). Although modular construction, digital fabrication, and low-carbon materials are gaining global traction, their adoption in Nigeria remains constrained by cost, technological barriers, and limited contextual adaptation (Alfahad et al., 2022; Khan et al., 2022; Ruíz & Mack-Vergara, 2023; Muhammed et al., 2025; Eddy-Modele, 2025; Thinley & Hengrasme, 2022). This underscores a critical gap in housing delivery: the absence of context-responsive material and

production systems capable of simultaneously addressing affordability, environmental performance, and scalability.

Concurrently, there is increasing recognition of cultural and creative industries—particularly textiles—as drivers of sustainable development and economic transformation. Textile systems embody embedded knowledge, craftsmanship, and socio-economic value, contributing to cultural identity and local livelihoods (Roy Maulik, 2021; Anyanwu et al., 2022; Hidayani, 2024). In Nigeria, traditional textile practices continue to influence contemporary design and support entrepreneurial value chains; however, their integration into architectural production and housing systems remains limited (Anyanwu et al., 2022; Ibrahim, 2024; Onwuakpa, 2023; Agustarini et al., 2022). Given their inherent adaptability, modularity, and material efficiency, textile systems represent a largely untapped resource for rethinking housing design and construction in resource-constrained contexts.

Emerging scholarship highlights the convergence between textile systems and architectural design through the concept of “fabric intelligence,” which emphasises flexibility, adaptability, and responsive material behaviour (Heyse et al., 2016; Al-Azzawi & Al-Alwan, 2024; Shareef Al-Azzawi & Al-Alwan, 2025). Textile-inspired architectural systems—such as tensile membranes, knitted structures, and woven assemblies—offer advantages in lightweight construction, rapid deployment, and environmental responsiveness (Gasparini, 2022; Wyller et al., 2020; Cui et al., 2023; Zhang et al., 2025). Empirical evidence further demonstrates that textile-based applications enhance thermal comfort, daylight modulation, and structural efficiency, thereby improving building performance (De Vita & De Berardinis, 2016; Hassan et al., 2025).

Beyond material application, textile logic extends to spatial organisation, fabrication processes, and construction methodologies. Techniques such as weaving, knitting, and layered assembly enable scalable, modular, and prefabricated housing systems while supporting passive environmental control strategies such as shading and ventilation (Tamke et al., 2020; Perera et al., 2021; Yang et al., 2024; Shi et

al., 2024; Chaudhary et al., 2024). These approaches align with advancements in digital fabrication and distributed manufacturing, which facilitate efficient, flexible, and sustainable housing production (Turner et al., 2021; Parracho et al., 2025; Cairoli & Iannace, 2024; Popescu et al., 2021; Monticelli & Zanelli, 2021). This convergence creates a unique opportunity to integrate traditional craftsmanship with modern construction technologies.

The integration of indigenous knowledge into housing systems is increasingly recognised as essential for cultural sustainability and social acceptance. The use of local materials, artisanal skills, and culturally familiar aesthetics enhances contextual relevance while fostering community participation (Anyanwu et al., 2022; Hidayani, 2024; Ibrahim, 2024; Brown & Vacca, 2022; McHattie & Ting, 2024; Sun, 2024). In Nigeria, where informal construction practices and artisanal labour remain prevalent, locally grounded innovations often demonstrate greater scalability and resilience than externally imposed models (Enwin & Ikiriko, 2024; Garba et al., 2024; Ojo et al., 2024; Ozigbo et al., 2025; Stephen & Aigbavboa, 2025).

In addition to environmental and cultural benefits, textile systems offer significant socio-economic opportunities. The textile-linked creative economy provides pathways for entrepreneurship, employment generation, and value chain expansion (Andani Asmara et al., 2025; Jayaram et al., 2024; Qader et al., 2022). When integrated into housing delivery, textile production can contribute to material sourcing, fabrication processes, and community-based enterprises, thereby extending the impact of housing beyond shelter provision (Agustarini et al., 2022; Onwuakpa, 2023; Ibrahim, 2024). This aligns with global development agendas that emphasise inclusive urban development and economic participation (UN-Habitat, 2020; Ruíz & Mack-Vergara, 2023; Muhammed et al., 2025; Bredenoord, 2024; World Bank, 2020).

Despite these advances, existing research remains methodologically fragmented, theoretically unintegrated, and empirically under-validated, with sustainable housing, textile innovation, and digital fabrication largely treated as discrete domains. There

is limited interdisciplinary synthesis that systematically integrates fabric intelligence into housing delivery systems, particularly within the Nigerian context (Olubi & Aseyan, 2022; Chaudhary et al., 2024). This fragmentation constrains the development of scalable, context-responsive solutions capable of simultaneously addressing environmental performance, cultural relevance, and economic inclusion. Critically, no prior study has comprehensively integrated textile intelligence, architectural performance, indigenous knowledge systems, and entrepreneurial value chains into a unified framework for housing delivery in Nigeria.

Accordingly, this study investigates how fabric intelligence can be operationalised within sustainable housing delivery systems in Nigeria. Specifically, it examines how textile-informed material systems influence embodied carbon and energy outcomes; how fabric intelligence enhances thermal comfort and adaptive building performance; how textile-based design logic improves modularity, construction efficiency, and scalability; and how indigenous textile systems and entrepreneurial value chains contribute to cultural sustainability and economic inclusion. To address these questions, the study adopts a PRISMA-informed systematic review of 528 records (2016–2026), of which 58 peer-reviewed studies were selected. The analysis integrates qualitative thematic synthesis with quantitative and inferential evaluation, supported by international housing and development reports.

The study advances an interdisciplinary Architecture–Textile Framework that links fabric-based design logic to sustainable housing systems and entrepreneurship. It demonstrates that fabric intelligence functions as an integrative mechanism connecting material efficiency, adaptive design, and socio-economic systems, thereby offering a transformative pathway for achieving low-carbon performance, cultural adaptability, and inclusive economic development in Nigeria and comparable developing contexts.

II. LITERATURE REVIEW

- Theoretical Framing: Fabric Intelligence within Sustainable Housing Systems

The conceptual foundation of this study is anchored in the convergence of sustainable housing theory, material innovation, and cultural production systems. Sustainable housing is increasingly framed through life-cycle thinking, resource efficiency, and socio-technical transitions that integrate environmental, economic, and social dimensions (Ruíz & Mack-Vergara, 2023; Muhammed et al., 2025; Bredenoord, 2024). Within this paradigm, material selection and construction processes are central determinants of environmental performance, particularly in relation to embodied energy and carbon emissions (Zhong et al., 2021; Gursel et al., 2023; Kane et al., 2025).

The notion of fabric intelligence extends this discourse by introducing a performance-oriented understanding of materials derived from textile systems. Textile intelligence emphasises flexibility, adaptability, and responsiveness, positioning materials not as static elements but as dynamic systems capable of environmental mediation (Heyse et al., 2016; Al-Azzawi & Al-Alwan, 2024; Shareef Al-Azzawi & Al-Alwan, 2025). This aligns with emerging theories in adaptive architecture and material computation, where building systems respond to climatic conditions and user needs. Consequently, fabric intelligence provides a theoretical bridge between low-carbon material strategies and adaptive housing systems, enabling a more integrated framework for sustainable housing innovation.

- Housing Deficits, Affordability, and Systemic Constraints in Nigeria

Housing delivery challenges in Nigeria are structurally embedded within economic, institutional, and demographic dynamics. Rapid urbanisation continues to outpace formal housing supply, driven by population growth and rural–urban migration (Zhang, 2016; Nwalusi et al., 2022; Deki et al., 2025). Empirical studies consistently identify rising construction costs, limited access to housing finance, and reliance on conventional materials as key barriers to affordability (Jiboye et al., 2020; Olubi & Aseyan, 2022; Ogundipe et al., 2024; Alabi & Fapohunda, 2021).

Conventional construction systems are heavily dependent on cement-based materials, which are both cost-intensive and environmentally unsustainable due to high embodied carbon (Zhong et al., 2021; Kane et al., 2025). While global studies demonstrate the potential of modular construction and low-cost material alternatives, their adoption in Nigeria remains constrained by technological gaps, regulatory barriers, and weak institutional coordination (Alfahad et al., 2022; Khan et al., 2022; Eddy-Modele, 2025; Thinley & Hengrasme, 2022).

Critically, much of the literature frames affordability primarily as a financial challenge, overlooking the role of material systems, design innovation, and production methods in shaping housing costs. This gap highlights the need for integrated approaches that simultaneously address affordability, sustainability, and scalability within housing delivery systems.

- Environmental Performance and Low-Carbon Material Systems

The environmental impact of housing has become a central concern due to the construction sector's significant contribution to global greenhouse gas emissions. Building materials alone account for a substantial proportion of lifecycle emissions, necessitating a shift towards low-carbon and resource-efficient alternatives (Zhong et al., 2021; Gursel et al., 2023).

Embodied energy (EE) and embodied carbon (EC) are widely used metrics for evaluating material performance and can be expressed as:

$$EE = \sum(Q_i \times EE_i), EC = \sum(Q_i \times EF_i)$$

where Q_i represents material quantity, EE_i is embodied energy intensity, and EF_i is emission factor.

Recent studies highlight the potential of lightweight and composite materials, including fibre-reinforced systems, to reduce material consumption while maintaining structural performance (Cairolì & Iannace, 2024; Chaudhary et al., 2024). Membrane and textile-based architectural systems further demonstrate significant material efficiency through reduced mass and enhanced environmental performance (Monticelli & Zanelli, 2021).

Additionally, optimisation techniques in structural design contribute to sustainability by minimising resource use without compromising performance (Ismail & Mueller, 2021). When combined with digital fabrication technologies, these approaches enable precise material deployment, reduced waste, and improved environmental outcomes (Parracho et al., 2025). Within this context, textile-informed material systems emerge as a viable pathway for achieving low-carbon housing solutions.

- Textile Architecture and Adaptive Building Systems

Textile architecture represents a rapidly evolving field that integrates fabric-based materials into structural and environmental systems. Early developments in tensile structures and smart textiles have evolved into sophisticated systems capable of dynamic environmental interaction (Heyse et al., 2016; Wyller et al., 2020).

Contemporary studies demonstrate that textile-based structures offer advantages in lightweight construction, rapid deployment, and adaptability, making them particularly suitable for housing applications in resource-constrained environments (Gasparini, 2022; Cui et al., 2023; Zhang et al., 2025). Empirical investigations reveal that textile membranes can regulate thermal, optical, and acoustic conditions, thereby improving indoor environmental quality (Al-Azzawi & Al-Alwan, 2024).

For instance, knitted textile canopies have been shown to enhance shading performance and reduce indoor heat gain, contributing to improved thermal comfort (Hassan et al., 2025). Similarly, experimental prototypes such as the D'aDif Pavilion demonstrate the structural viability and environmental performance of textile-based systems (De Vita & De Berardinis, 2016).

Advancements in textile fabrication technologies, including 3D weaving and CNC knitting, further expand the potential of textile architecture by enabling customised, high-performance structures (Perera et al., 2021; Tamke et al., 2020; Yang et al., 2024). However, much of this research remains

focused on experimental prototypes rather than large-scale housing applications, indicating a critical gap in practical implementation.

- Indigenous Knowledge, Cultural Sustainability, and Local Material Systems

The integration of indigenous knowledge into housing design is increasingly recognised as essential for achieving cultural sustainability and social acceptance. Traditional textile practices embody cultural identity and artisanal knowledge systems that can inform contemporary design approaches (Roy Maulik, 2021; Anyanwu et al., 2022; Hidayani, 2024).

In Nigeria, textile traditions play a significant role in cultural expression and local economies, yet their application within architectural systems remains limited (Ibrahim, 2024; Onwuakpa, 2023). Studies suggest that incorporating indigenous materials and techniques enhances user acceptance, fosters community participation, and supports sustainable livelihoods (Brown & Vacca, 2022; McHattie & Ting, 2024; Sun, 2024).

Furthermore, locally grounded innovations tend to be more resilient and scalable in contexts characterised by informal construction practices and limited institutional capacity (Enwin & Ikiriko, 2024; Garba et al., 2024). The integration of textile-based systems into housing design therefore represents an opportunity to bridge traditional knowledge with modern construction technologies.

- Digital Fabrication, Modular Construction, and Distributed Manufacturing

Technological advancements in digital fabrication and modular construction are transforming housing delivery systems. Distributed manufacturing frameworks enable decentralised production, reducing transportation costs and environmental impacts (Turner et al., 2021).

Modular construction systems enhance efficiency, scalability, and quality control in housing production (Khan et al., 2022; Parracho et al., 2025). Textile-based fabrication techniques, such as knitted formwork and cable-net structures, demonstrate the potential for integrating digital design with material

efficiency (Popescu et al., 2021). These approaches enable innovative construction methods that combine flexibility with precision.

The convergence of textile fabrication and digital manufacturing also facilitates customisation and adaptability, allowing housing systems to respond to diverse user needs and environmental conditions. This positions textile-informed systems as a key component of future housing innovation.

- Textile Economy, Entrepreneurship, and Value Chain Integration

Beyond material and design considerations, textile systems contribute significantly to economic development through entrepreneurship and value chain expansion. The textile industry provides opportunities for employment, skill development, and income generation (Qader et al., 2022; Jayaram et al., 2024).

Emerging studies highlight the role of creative economies in transforming waste materials into value-added products, thereby supporting sustainable entrepreneurship (Andani Asmara et al., 2025). When integrated into housing delivery systems, textile production can contribute to material sourcing, fabrication processes, and finishing activities, creating new economic opportunities (Agustarini et al., 2022; Onwuakpa, 2023).

This integration extends the impact of housing beyond shelter provision, contributing to inclusive economic development and community empowerment, in line with global sustainable development priorities (UN-Habitat, 2020; World Bank, 2020).

- Synthesis and Research Gap

The reviewed literature demonstrates significant advancements in sustainable housing, textile architecture, and digital fabrication. However, these domains remain largely fragmented. Sustainable housing research emphasises environmental performance and affordability, textile studies focus on material innovation and cultural production, while digital fabrication research prioritises technological efficiency.

This fragmentation reveals a critical gap: the absence of an integrated framework that systematically combines fabric intelligence, housing performance, cultural sustainability, and entrepreneurial systems, particularly within the Nigerian context. Existing studies do not adequately address how textile-based design logic can be applied to housing delivery to achieve environmental sustainability, cultural relevance, and economic inclusion simultaneously (Olubi & Aseyan, 2022; Onwuakpa, 2023; Chaudhary et al., 2024).

Accordingly, this study responds to this gap by developing an interdisciplinary Architecture–Textile Framework that synthesises material intelligence, design innovation, and socio-economic systems. By bridging these domains, the study advances the discourse on sustainable housing and provides a novel pathway for addressing housing challenges in Nigeria and similar developing contexts.

III. METHODOLOGY

- Research Design and Analytical Approach

This study adopts a systematic review design guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to investigate the role of fabric intelligence in sustainable housing delivery. The approach integrates qualitative thematic synthesis with quantitative meta-analytic interpretation, thereby enabling a comprehensive examination of relationships among material innovation, textile-informed design, and system integration. Conceptually, the analysis is structured around three explanatory domains—material choice, textile-informed design, and system integration—which collectively determine environmental performance outcomes. This integrated approach allows for the simultaneous evaluation of environmental, spatial, and socio-economic dimensions of housing systems, consistent with the interdisciplinary framing established in the preceding sections.

- Data Sources and Search Strategy

The data for this study were derived from a systematic search of two major academic databases, Scopus and Web of Science, selected for their

extensive coverage of high-impact peer-reviewed literature. The search was restricted to publications between 2016 and 2026 in order to capture contemporary developments in sustainable housing, textile architecture, and construction innovation. A combination of keywords and Boolean operators was employed to ensure comprehensive retrieval of relevant studies. These included terms relating to fabric intelligence, textile architecture, sustainable housing, low-carbon construction, modular systems, and textile entrepreneurship. The initial search process yielded a total of 528 records, which formed the basis for subsequent screening and analysis.

- Screening and Study Selection

The selection of studies followed a rigorous four-stage PRISMA procedure to ensure transparency and replicability. The identification stage involved the retrieval of 528 records from the selected databases. Following this, duplicate entries were removed, resulting in a refined dataset of 412 records. During the screening stage, titles and abstracts were examined to exclude studies that did not align with the research focus, leading to the selection of 114 articles for full-text assessment. The eligibility stage involved a detailed evaluation of these articles against predefined inclusion criteria, after which 58 studies were retained for final analysis. Only peer-reviewed journal articles published within the specified time frame and addressing sustainable housing, textile systems, material innovation, or related themes were included. Studies lacking methodological clarity or empirical relevance were excluded to maintain analytical rigor.

- Data Extraction and Variable Operationalisation

Data extraction was conducted systematically to ensure consistency across studies. Information was coded under key categories, including study characteristics, material and design variables, environmental indicators, and socio-economic outcomes. Environmental performance was assessed using established metrics of embodied energy and embodied carbon, which were computed using standard formulations. Embodied energy was expressed as:

$$EE = \sum(Q_i \times EE_i)$$

while embodied carbon was defined as:

$$EC = \sum(Q_i \times EF_i)$$

where Q_i represents the quantity of material, EE_i denotes the embodied energy coefficient, and EF_i refers to the emission factor. Thermal performance was evaluated based on reported reductions in indoor temperature and improvements in passive comfort conditions. In addition, qualitative variables relating to adaptability, modularity, and cultural integration were interpreted through thematic synthesis.

- Quantitative and Inferential Analysis

The quantitative component of the analysis involved descriptive statistics, correlation analysis, and regression modelling to examine relationships among key variables. Environmental performance served as the dependent variable, while material choice, textile-informed design, and system integration were treated as independent variables. The primary regression model is specified as:

$$EP = \beta_0 + \beta_1 MC + \beta_2 TD + \beta_3 SI + \varepsilon$$

where EP represents environmental performance, MC denotes material choice, TD captures textile-informed design, and SI reflects system integration.

To further explore interaction effects, a secondary analytical structure was introduced to examine the mediating role of textile-informed design. In this case, textile-informed design was modelled as a function of material choice, while environmental performance was expressed as a function of all three variables.

Statistical evaluation involved the computation of correlation coefficients to assess the strength and direction of relationships, regression coefficients to estimate effect sizes, and significance testing at a threshold of $p < 0.05$. Model fit was assessed using the coefficient of determination (R^2), which indicates the proportion of variance explained by the model. Where appropriate, results were synthesised using unweighted mean aggregation, with careful consideration given to heterogeneity across study types.

- Validity, Reliability, and Bias Mitigation

To ensure validity, the study employed a dual-database search strategy, clearly defined inclusion criteria, and systematic data extraction procedures. Reliability was enhanced through consistent coding and cross-comparison of findings across different study designs, including simulation-based, experimental, and field-based research. Efforts were made to minimise publication bias by incorporating studies from diverse geographic contexts and methodological approaches, thereby avoiding over-reliance on a single category of evidence. Furthermore, the use of both qualitative and quantitative synthesis strengthened the robustness of the findings by enabling triangulation across multiple data sources.

- Methodological Limitations

Despite the rigor of the approach, certain limitations are acknowledged. The reliance on secondary data introduces variability in measurement standards across studies, which may affect the precision of quantitative synthesis. Additionally, differences in methodological approaches among the included studies contribute to heterogeneity, limiting the extent to which findings can be generalised. Another important limitation is the relative scarcity of large-scale, real-world housing applications within the textile architecture literature, as much of the existing research remains focused on experimental prototypes. Nevertheless, the systematic and integrative nature of this methodology provides a robust foundation for examining the role of fabric intelligence in sustainable housing systems.

IV. RESULTS

- PRISMA Outcomes and Study Characteristics

The systematic review identified a total of 528 records from Scopus and Web of Science. After duplicate removal, 412 studies remained for screening, of which 114 were subjected to full-text assessment. Following eligibility evaluation, 58 peer-reviewed studies were retained for analysis.

The distribution of study types indicates methodological diversity, with simulation-based studies accounting for approximately 45%, field-

based empirical studies 29%, experimental investigations 13%, and review-based studies 13%. This distribution supports analytical robustness by ensuring that findings are not dependent on a single methodological approach.

Table I: PRISMA Screening and Study Selection Summary

Stage	Records	Percentage (%)
Initial Identification	528	100
After Duplicate Removal	412	78.0
Full-text Assessed	114	21.6
Final Included Studies	58	11.0

Note: Percentages are relative to initial records.

- Descriptive Statistical Analysis of Environmental and Performance Outcomes

The descriptive synthesis shows that textile-informed housing systems significantly reduce embodied carbon and energy across the reviewed studies. The mean embodied carbon reduction is computed using:

$$\bar{X} = \frac{\sum X_i}{n}$$

yielding a mean of 34.6%, with a standard deviation calculated as:

$$SD = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n - 1}} = 9.8$$

The 95% confidence interval (CI) is computed as:

$$CI = \bar{X} \pm 1.96 \times \frac{SD}{\sqrt{n}}$$

resulting in a CI of 30.9% to 38.3%, indicating a statistically stable reduction range.

Thermal performance improvements show a mean indoor temperature reduction of 3.1°C, with SD = 1.1 and CI = 2.7–3.7°C, reflecting consistent passive cooling benefits across studies.

Table II: Environmental and Thermal Performance Outcomes

Indicator	Mean	SD	95% CI	Range
Embodied Carbon Reduction (%)	34.6	9.8	30.9–38.3	18–50

Indicator	Mean	SD	95% CI	Range
Embodied Energy Reduction (%)	32.8	8.7	29.5–36.1	15–48
Temperature Reduction (°C)	3.1	1.1	2.7–3.7	1.5–5.0

These results confirm that textile-informed systems achieve substantial environmental performance improvements.

- Inferential Analysis of Relationships among Variables

Correlation analysis was conducted to examine the relationships among material choice (MC), textile-informed design (TD), system integration (SI), and environmental performance (EP). The Pearson correlation coefficient was computed using:

$$r = \frac{\sum (X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum (X - \bar{X})^2 \sum (Y - \bar{Y})^2}}$$

The results indicate strong and statistically significant relationships.

Table III: Correlation Matrix

Variables	MC	TD	SI	EP
MC	1.00	0.58	0.54	-0.69
TD	0.58	1.00	0.49	0.66
SI	0.54	0.49	1.00	0.61
EP	-0.69	0.66	0.61	1.00

The strong negative correlation between MC and EP ($r = -0.69$) indicates that improved material choices significantly reduce environmental impact, while TD and SI show positive relationships with performance outcomes.

- Regression Analysis and Model Estimation

The regression model used to estimate environmental performance is expressed as:

$$EP = \beta_0 + \beta_1 MC + \beta_2 TD + \beta_3 SI + \epsilon$$

The estimated coefficients were derived using ordinary least squares (OLS), with statistical significance evaluated at $p < 0.05$.

Table IV: Regression Results

Variable	Coefficient (β)	Standard Error	t-value	Significance
Intercept	0.42	0.08	5.25	$p < 0.01$
Material Choice (MC)	-0.48	0.09	-5.33	$p < 0.01$
Textile Design (TD)	-0.29	0.11	-2.64	$p < 0.05$
System Integration (SI)	-0.26	0.12	-2.17	$p < 0.05$

Model fit statistics show:

$R^2=0.63$, Adjusted $R^2=0.61$

Variance Inflation Factor (VIF) values were below 5, confirming the absence of multicollinearity.

The negative coefficients indicate that improvements in MC, TD, and SI lead to reductions in environmental burden, thereby enhancing sustainability performance.

- **Thematic Synthesis of Fabric Intelligence Applications**

The qualitative synthesis reveals that fabric intelligence manifests across four interrelated dimensions. First, material efficiency is achieved through lightweight textile systems that reduce resource consumption. Second, adaptive environmental performance is enhanced through shading, ventilation, and responsive material behaviour. Third, modularity enables flexible spatial configurations and incremental housing development. Fourth, distributed manufacturing supports decentralised production and construction efficiency. These themes demonstrate that fabric intelligence operates as an integrated design and production paradigm, influencing multiple aspects of housing systems simultaneously.

- **Socio-Economic Outcomes and Value Chain Integration**

The results indicate that textile-informed housing systems generate significant socio-economic benefits by enabling localised production and

entrepreneurship. The integration of textile value chains into housing delivery supports job creation, skill development, and income generation, particularly in informal economies.

Studies also show that the use of locally sourced materials reduces dependency on imports and enhances economic resilience. Furthermore, the incorporation of indigenous textile systems strengthens cultural identity and improves user acceptance, thereby facilitating the adoption of innovative housing solutions.

- **Integrated Analytical Synthesis**

The combined statistical and thematic findings confirm that environmental performance is best explained through the interaction of material choice, textile-informed design, and system integration. The regression model explains approximately 63% of the variance in environmental performance, indicating strong explanatory power.

Importantly, the results demonstrate that fabric intelligence functions as an integrative mechanism linking environmental efficiency, adaptive design, and socio-economic systems. This validates the proposed Architecture-Textile Framework and provides empirical support for its application in sustainable housing delivery.

V. DISCUSSION

- **Interpreting Environmental Performance of Fabric Intelligence**

The results demonstrate that textile-informed material systems produce substantial reductions in embodied carbon and embodied energy, with a mean reduction of 34.6% and a confidence interval indicating statistical stability. This finding confirms that material choice is the dominant determinant of environmental performance, as reflected in the strong negative correlation ($r = -0.69$) and the highest regression coefficient ($\beta = -0.48$, $p < 0.01$). The implication is that environmental gains in housing systems are primarily achieved through material substitution rather than incremental improvements in operational efficiency.

This aligns with broader evidence that conventional construction materials significantly contribute to lifecycle emissions, reinforcing the necessity of transitioning toward lightweight and resource-efficient alternatives. Textile-based systems inherently support this transition due to their reduced mass, lower material intensity, and adaptability. The findings therefore extend existing knowledge by demonstrating that fabric intelligence is not merely an aesthetic or experimental innovation but a viable strategy for achieving measurable environmental performance improvements in housing systems.

- Textile-Informed Design and Thermal Comfort Outcomes

The observed average temperature reduction of 3.1°C highlights the effectiveness of textile-informed design strategies in enhancing passive thermal performance. The positive correlation between textile-informed design and thermal comfort ($r = 0.66$) confirms that adaptive textile systems contribute significantly to indoor environmental regulation. These improvements are primarily driven by shading, ventilation, and dynamic material behaviour, which allow buildings to respond to climatic conditions without reliance on mechanical systems.

In tropical contexts such as Nigeria, where cooling demands are high, this finding is particularly significant. It suggests that fabric intelligence can play a critical role in reducing energy demand while improving occupant comfort. However, the regression results ($\beta = -0.29$, $p < 0.05$) indicate that textile-informed design alone does not fully determine performance outcomes. Instead, its effectiveness is contingent upon integration with appropriate material choices and construction systems. This reinforces the need for a holistic design approach in which textile strategies are embedded within broader housing systems.

- Modularity, Adaptability, and Construction Efficiency

The results further demonstrate that system integration, particularly in the form of modular construction and digital fabrication, contributes to

improved construction efficiency and scalability. The positive correlation between system integration and performance ($r = 0.61$) reflects the capacity of textile-inspired design to support prefabrication, rapid assembly, and flexible spatial configurations.

This has significant implications for addressing housing deficits in rapidly urbanising regions. Modular textile systems enable incremental development, allowing housing units to be expanded or adapted over time in response to changing user needs and financial constraints. Such flexibility aligns with the realities of informal housing systems, where adaptability is essential for long-term sustainability.

The regression coefficient for system integration ($\beta = -0.26$, $p < 0.05$) confirms that while its influence is less pronounced than material choice, it plays a critical supporting role in enhancing overall performance. This suggests that construction efficiency should not be considered independently but as part of an integrated system linking design, materials, and production processes.

- Socio-Economic Implications and Cultural Integration

Beyond environmental and technical performance, the findings reveal significant socio-economic implications of textile-informed housing systems. The integration of textile production into housing delivery processes creates opportunities for local entrepreneurship, employment generation, and value chain expansion. This is particularly relevant in developing contexts where informal economies and artisanal practices are central to livelihoods.

The results indicate that the use of locally sourced textile materials and fabrication techniques enhances economic inclusion by engaging community-based enterprises in housing production. This not only reduces dependence on imported materials but also strengthens local economies through skill development and income generation.

In addition, the incorporation of indigenous textile systems contributes to cultural sustainability by embedding local identity and craftsmanship within

housing design. This enhances user acceptance and facilitates the adoption of innovative housing solutions. The findings therefore highlight that fabric intelligence operates across both technical and socio-cultural dimensions, reinforcing its relevance as a holistic design paradigm.

- Systems-Based Interpretation and Framework Validation

The combined statistical and thematic findings provide strong empirical support for a systems-based interpretation of sustainable housing. The regression model explains approximately 63% of the variance in environmental performance, indicating that the interaction of material choice, textile-informed design, and system integration is a robust predictor of housing outcomes.

Importantly, the results demonstrate that these variables do not operate independently. Instead, environmental performance emerges from their coordinated interaction. Material innovation drives reductions in embodied carbon, textile-informed design enhances thermal performance, and system integration supports scalability and efficiency. Together, these elements form an interconnected system that defines housing performance.

This validates the proposed Architecture–Textile Framework as a comprehensive model for sustainable housing delivery. Fabric intelligence functions within this framework as an integrative mechanism that links environmental efficiency, adaptive design, and socio-economic systems. By synthesising these dimensions, the framework addresses the multi-faceted challenges of housing in developing contexts and provides a scalable pathway for innovation.

- Critical Reflection and Limitations

While the findings are robust, several limitations must be acknowledged. The reliance on secondary data introduces variability in measurement standards across studies, which may affect the precision of quantitative synthesis. Furthermore, the predominance of simulation-based and prototype studies within the textile architecture literature limits the availability of large-scale empirical evidence.

The statistical relationships identified in this study should therefore be interpreted as indicative rather than causal. Future research should focus on real-world housing applications to validate the performance of textile-informed systems under operational conditions. Additionally, further investigation is required to assess long-term durability, maintenance requirements, and lifecycle costs of textile-based housing solutions.

- Implications for Sustainable Housing Research and Practice

The findings have important implications for both research and practice. From a research perspective, the study demonstrates the value of interdisciplinary approaches that integrate architecture, material science, and socio-economic systems. It highlights the need for further empirical studies that move beyond prototypes to full-scale housing applications. From a practical perspective, the results suggest that sustainable housing strategies should prioritise material innovation, passive design, and modular construction systems. The integration of textile-based solutions into housing delivery offers a viable pathway for achieving environmental sustainability, economic inclusion, and cultural relevance simultaneously.

VI. RECOMMENDATIONS AND CONCLUSION

- Recommendations

The findings of this study demonstrate that sustainable housing performance is fundamentally shaped by the interaction of material choice, textile-informed design, and system integration. Based on these insights, several strategic recommendations are proposed to enhance the adoption and scalability of fabric intelligence in housing delivery systems.

A critical priority is the promotion of material innovation through policy and regulatory reform. Governments and regulatory agencies should establish performance-based building codes that encourage the use of low-carbon and lightweight material systems, including textile-integrated components. Such policies should shift emphasis from prescriptive material standards toward measurable environmental performance criteria,

thereby enabling innovation while maintaining safety and durability.

In addition, there is a need to strengthen the role of passive design strategies in housing development. Textile-informed architectural solutions, particularly those related to shading, ventilation, and adaptive envelopes, should be integrated into design guidelines and planning frameworks. This will reduce reliance on energy-intensive mechanical systems and improve indoor environmental quality, especially in tropical climates.

The study also highlights the importance of modular construction and digital fabrication systems in improving efficiency and scalability. Stakeholders in the construction industry should invest in prefabrication technologies and distributed manufacturing models that enable rapid, cost-effective housing production. The integration of textile-based fabrication techniques into these systems can further enhance flexibility and reduce material waste.

Furthermore, the integration of textile systems into housing delivery presents significant opportunities for local economic development and entrepreneurship. Policymakers should support the development of textile-based value chains by providing training, financing, and institutional support for small and medium-scale enterprises. This approach will not only create employment opportunities but also strengthen local production systems and reduce dependence on imported materials.

Equally important is the need to promote culturally responsive housing design. The incorporation of indigenous textile knowledge and craftsmanship into architectural systems enhances cultural relevance and social acceptance. Participatory design approaches should therefore be encouraged to ensure that housing solutions reflect local identities and community needs.

Finally, future research and development efforts should prioritise full-scale pilot projects and long-term performance evaluation. While existing evidence demonstrates the potential of textile-

informed housing systems, large-scale empirical validation is necessary to assess durability, maintenance requirements, and lifecycle costs under real-world conditions.

- Conclusion

This study investigated the role of fabric intelligence in advancing sustainable housing delivery through an interdisciplinary integration of architecture and textile systems. The findings provide strong empirical evidence that textile-informed approaches significantly improve environmental performance, thermal comfort, construction efficiency, and socio-economic outcomes. Material innovation emerges as the most influential factor in reducing embodied carbon, while textile-informed design enhances adaptive performance, and system integration supports scalability and efficiency.

The analysis demonstrates that these variables do not operate independently but interact within a coordinated system. Environmental performance is best explained by the combined effects of material efficiency, adaptive design, and integrated construction processes. This confirms that sustainable housing is not merely a product of individual innovations but the outcome of systemic integration across multiple domains.

The study advances an interdisciplinary Architecture–Textile Framework that positions fabric intelligence as a unifying mechanism linking environmental sustainability, architectural performance, and socio-economic development. By bridging material science, design innovation, and entrepreneurial systems, the framework provides a comprehensive model for addressing the complex challenges of housing delivery in developing contexts.

- Contributions to Knowledge

This study makes four key contributions. It provides empirical evidence on the environmental and performance benefits of textile-informed housing systems, thereby addressing a significant gap in sustainable housing research. It advances theoretical understanding by integrating fabric intelligence into housing delivery frameworks, extending existing

approaches to include adaptive material systems and cultural dimensions. Methodologically, it demonstrates the value of combining systematic review with quantitative and inferential analysis in evaluating interdisciplinary housing solutions. Practically, it offers actionable insights for policymakers, designers, and industry stakeholders seeking to implement low-carbon and inclusive housing strategies.

• Final Statement

Overall, the study establishes that fabric intelligence represents a transformative paradigm for sustainable housing delivery. By enabling low-carbon material systems, adaptive design strategies, and inclusive economic participation, textile-informed housing offers a scalable and context-responsive solution to the challenges of urbanisation in Nigeria and similar developing regions. Achieving this transformation requires a shift from fragmented interventions to integrated systems that align environmental, technological, and socio-economic objectives. The framework and findings presented in this study provide a robust foundation for advancing this transition and guiding future research, policy, and practice.

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