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## AI-Driven Material Selection and Maintenance in Cultural Centre Design in Delta State, Nigeria

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### ABSTRACT

Artificial intelligence (AI) has emerged as a transformative force in architecture and construction, offering new methods for optimizing design, material selection, and building maintenance. Cultural centres, which serve as hubs of heritage, community, and creativity, face persistent challenges in balancing aesthetic expression with durability, sustainability, and lifecycle performance. Traditional approaches to material selection often fail to account for the complex interplay between environmental conditions, cultural symbolism, and long-term maintenance costs. This study aims to investigate how AI-driven strategies can enhance material selection and predictive maintenance in cultural centre design. Employing a qualitative methodology based on literature review and case study analysis, the research synthesizes findings from recent scholarship on AI applications in architecture, smart building systems, and lifecycle management. Results reveal that AI tools can simultaneously analyze material properties, environmental impacts, and lifecycle costs, enabling architects to make more informed decisions. Furthermore, predictive maintenance technologies powered by AI can forecast material degradation, optimize repair schedules, and reduce operational costs. The study concludes that integrating AI into cultural centre design not only improves sustainability and resilience but also strengthens the cultural and functional value of these buildings. The implications suggest that architects and designers should embrace AI as a strategic partner in achieving sustainable and culturally responsive architecture.

**Keywords:** Artificial Intelligence, Material Selection, Cultural Centre Design, Building Maintenance, Smart Buildings

### INTRODUCTION

Cultural centres are more than architectural structures; they are symbolic spaces that embody collective identity, foster social cohesion, and preserve heritage. They serve as hubs for education, creativity, and civic engagement, making their design and construction critical to both cultural sustainability and urban development. The architectural quality of cultural centres depends heavily on material selection, which influences aesthetics, durability, environmental performance, and long-term maintenance requirements (Oke & Aigbavboa, 2020). These buildings are expected to endure for decades, yet their resilience is often compromised by poor material choices and inadequate maintenance strategies. In Nigeria, particularly in Delta State, cultural centres and other public buildings face persistent challenges in material selection and maintenance. Many facilities deteriorate prematurely due to the use of substandard materials, poor adaptation to climatic conditions, and limited consideration of lifecycle costs (Olanrewaju & Abdul-Aziz, 2015). Maintenance problems such as escalating costs, inefficient repair schedules, and environmental degradation compromise the usability and cultural value of these centres. These challenges mirror broader construction quality issues observed across Nigerian cities, where weak enforcement mechanisms, limited institutional capacity, and poor compliance culture undermine building performance (Akanbi et al., 2018). Scholars such as Ibitoye (2025) have noted that tropical climates characterized by heavy rainfall, humidity, and heat accelerate material degradation, while Olaoye (2023) emphasizes that cultural buildings in Nigeria often fail to integrate climate-responsive materials, leading to recurring structural failures.

Artificial intelligence (AI) has emerged as a transformative tool in architecture and construction, offering solutions to these persistent challenges. AI systems can analyze large material databases and recommend optimal materials based on performance, sustainability, and cost (Alghusni et al., 2025). Machine learning models and digital twin frameworks further enable predictive maintenance by simulating

material performance under varying environmental conditions and forecasting potential failures (Torzoni et al., 2023; Li et al., 2026). Predictive maintenance technologies powered by AI allow facility managers to anticipate material degradation, optimize repair schedules, and reduce operational costs (Bouabdallaoui et al., 2021; Zheng et al., 2025). This shift from reactive to proactive maintenance is particularly important in cultural centres, which must remain functional and safe for large public gatherings. The reliance on traditional approaches often results in poor material choice, high maintenance costs, environmental degradation, and a lack of data-driven decision making. These shortcomings highlight the need for AI-driven strategies that integrate material selection with predictive maintenance to ensure cultural centres remain resilient and sustainable throughout their lifecycle. AI-driven optimization can improve lifecycle performance, reduce environmental impact, and enhance the cultural and functional value of these buildings (Chen et al., 2024). By embedding AI into design and maintenance, cultural centres can evolve into dynamic systems capable of responding to environmental changes, usage demands, and cultural shifts.

The aim of this study is to evaluate the role of AI in improving material selection and maintenance strategies in cultural centre design in Delta State, Nigeria. To achieve this aim, the study pursues the following objectives:

1. Examine traditional material selection practices in cultural buildings.
2. Identify AI tools used for material analysis and maintenance prediction.
3. Evaluate how AI improves durability, sustainability, and lifecycle cost.
4. Propose a framework for AI-driven material selection and maintenance in cultural centres.

The significance of this study lies in its potential contributions to multiple stakeholders. For architects, it provides data-driven tools for sustainable and culturally responsive design (Eastman et al., 2018; Ding et al., 2018). AI-driven material selection allows architects to balance cultural symbolism with technical performance, ensuring that materials chosen are not only aesthetically appropriate but also durable and environmentally sustainable. For facility managers, predictive maintenance strategies reduce costs and improve efficiency (Villa et al., 2022; Hamilton & Ali, 2026). By leveraging AI, managers can move from reactive to proactive maintenance, anticipating failures before they occur and scheduling interventions that minimize disruption. For cultural institutions, AI integration ensures long-term durability and functionality of cultural centres (Ni, 2025). This is particularly important in Nigeria, where cultural centres often serve as multi-functional spaces that must withstand heavy usage. Finally, for researchers, this study expands the discourse on AI applications in architecture, construction technology, and building lifecycle management (Chen et al., 2024; Lu et al., 2020). By situating the research within both local challenges and global technological advancements, this study underscores the importance of integrating AI into cultural centre design. Just as building information modeling (BIM) frameworks have transformed construction management by enabling data-driven decision making (Pärn et al., 2017; Love et al., 2014), AI-driven approaches in Delta State can provide the analytical and predictive capabilities necessary to ensure sustainable, resilient, and culturally meaningful architecture. The integration of AI into cultural centre design represents not merely a technological upgrade but a paradigm shift in how architects, engineers, and managers conceptualize and sustain cultural infrastructure.

## LITERATURE REVIEW

The literature on cultural centre architecture emphasizes their role as multifunctional spaces that embody cultural identity, foster social cohesion, and provide platforms for education, creativity, and civic engagement. These centres typically incorporate auditoriums, galleries, libraries, studios, and communal areas, each requiring specific material and design considerations to ensure usability and longevity. Durable materials are particularly important because cultural centres experience high foot traffic and diverse usage patterns, and their resilience directly impacts lifecycle costs, sustainability, and the preservation of cultural heritage embedded in the architecture (Oke & Aigbavboa, 2020; Olanrewaju & Abdul-Aziz, 2015). Scholars such as Ibitoye (2025) have argued that tropical climates characterized by heavy rainfall, humidity, and heat accelerate material degradation, making the choice of materials a decisive factor in the long-term survival of cultural infrastructure. Olaoye (2023) further notes that cultural buildings in Nigeria often fail to integrate climate-responsive materials, leading to recurring structural failures and high maintenance burdens.

Material selection in building design is a complex process influenced by structural performance, climate adaptability, cost, and durability. In tropical regions such as Nigeria, climate considerations are

paramount, as materials must resist moisture, heat, and biological degradation. Poor material choices often lead to high maintenance costs and reduced building lifespan. AI systems enhance this process by simultaneously processing multiple parameters such as structural performance, carbon footprint, and lifecycle cost, enabling architects to select materials that balance sustainability, durability, and affordability (Alghusni et al., 2025). By integrating environmental data, AI can recommend materials that are not only cost-effective but also resilient under specific climatic conditions, thereby addressing the shortcomings of traditional selection methods (Villa et al., 2022). Ibitoye (2025) stresses that the integration of technology into material selection is essential for tropical contexts, where environmental stressors demand innovative solutions. Artificial intelligence has become increasingly integrated into architecture and construction, transforming design, planning, and management processes. In design, AI supports generative modeling, enabling architects to explore multiple design alternatives quickly and efficiently (Chen et al., 2024). Within Building Information Modeling (BIM), AI enhances data analysis, clash detection, and lifecycle management, improving collaboration and reducing errors (Eastman et al., 2018; Pärn et al., 2017). Olaoye (2023) highlights that cultural architecture in Nigeria is deeply influenced by socio-cultural and liturgical factors, and AI can help reconcile these symbolic requirements with technical performance. In construction management, AI applications include project scheduling, resource optimization, and risk assessment. Machine learning and digital technologies are increasingly used across the building lifecycle to improve efficiency and sustainability (Zheng et al., 2025). These tools allow construction professionals to anticipate challenges, optimize workflows, and ensure compliance with sustainability standards.

AI-driven material selection leverages machine learning algorithms and multi-objective optimization techniques to evaluate material performance across diverse criteria. Algorithms can analyze historical data, environmental conditions, and sustainability metrics to recommend optimal materials for specific projects (renderkits.com, 2023). Multi-objective optimization ensures that material choices balance durability, cost, and environmental impact. For example, AI can assess trade-offs between carbon footprint and lifecycle cost, enabling architects to select materials that align with sustainability goals while remaining economically viable (Villa et al., 2022). Sustainability assessment is further enhanced by AI's ability to simulate long-term performance under varying climatic conditions, ensuring that cultural centres remain resilient and functional over time (Alghusni et al., 2025). Ibitoye (2025) emphasizes that such optimization is critical in Nigeria, where resource constraints demand cost-effective yet durable solutions. AI also plays a transformative role in building maintenance. Predictive maintenance technologies use historical and real-time data to forecast material degradation and system failures, allowing facility managers to schedule interventions proactively (Bouabdallaoui et al., 2021). Digital twin frameworks replicate physical buildings in virtual environments, enabling continuous monitoring and simulation of performance (Torzoni et al., 2023; Li et al., 2026). IoT sensors integrated with AI systems provide real-time data on structural health, environmental conditions, and usage patterns. This data-driven approach allows for precise maintenance planning, reducing costs and extending building lifespan (Ni, 2025). AI can predict material degradation and maintenance needs using historical and real-time data, ensuring that cultural centres remain safe, functional, and sustainable. Olaoye (2023) points out that integrating AI into cultural architecture can help address recurring maintenance challenges by providing proactive solutions that align with socio-cultural expectations.

Despite these advancements, a notable research gap exists. While AI applications in construction and building maintenance are widely studied, few studies focus specifically on cultural centres in Nigeria. Existing research emphasizes AI in general construction management, smart buildings, and sustainability, but there is limited exploration of how AI can be applied to material lifecycle management in cultural architecture. The intersection of AI, material selection, and cultural centre design remains underexplored, particularly in the Nigerian context where climatic challenges and resource constraints demand innovative solutions. This research therefore addresses a critical gap by examining how AI-driven material selection and predictive maintenance strategies can enhance the durability, sustainability, and cultural relevance of cultural centres in Delta State. By linking AI applications with cultural architecture, the study contributes to both academic discourse and practical solutions for sustainable cultural infrastructure (Ibitoye, 2025; Olaoye, 2023; Chen et al., 2024).

## RESEARCH METHOD

The methodology adopted for this study is qualitative and exploratory in nature, designed to provide a comprehensive understanding of how artificial intelligence can be integrated into material selection and maintenance strategies for cultural centre design. A qualitative approach is most appropriate because the research seeks to explore complex relationships between technology, architecture, and cultural infrastructure, rather than to quantify variables. This approach allows for a deeper examination of contextual factors such as climate, cultural symbolism, and lifecycle performance, which are critical in the Nigerian setting.

Data collection was conducted through a systematic literature review, case study analysis, and optional expert interviews. The literature review involved the identification and synthesis of scholarly articles, conference papers, and technical reports published between 2018 and 2025, focusing on AI applications in architecture, material selection, predictive maintenance, and smart building systems. Case studies of cultural centres, particularly those in Nigeria and comparable tropical regions, were analyzed to understand traditional material selection practices and maintenance challenges. In addition, insights from architects, engineers, and facility managers were considered to capture professional perspectives on the practical relevance of AI-driven solutions.

Data analysis was carried out using thematic analysis, which involved coding, thematic grouping, and synthesis of findings. Recurring themes such as durability, sustainability, lifecycle cost, and predictive maintenance were identified across the literature and case studies. Coding allowed for the systematic categorization of data, while thematic grouping facilitated the identification of patterns and best practices. The synthesis of findings provided a coherent framework that connects AI applications with cultural centre design and maintenance.

The study also examined specific AI tools and frameworks relevant to material selection and building maintenance. These include machine learning models that analyze material performance data, predictive maintenance systems that forecast degradation, digital twin technologies that simulate building performance, and decision support systems that integrate multiple parameters such as cost, environmental impact, and durability. Each of these frameworks was evaluated for its applicability to cultural centre design, with particular attention to their ability to address challenges in tropical climates and resource-constrained contexts.

The justification for this methodology lies in its ability to provide both academic and practical insights. By combining literature review, case study analysis, and thematic synthesis, the research captures the breadth of existing knowledge while contextualizing it within the specific challenges of cultural centres in Nigeria. The inclusion of AI tool examination ensures that the study is not only theoretical but also technologically grounded, offering practical relevance to architects, engineers, and facility managers. This comprehensive methodology thus enables a nuanced understanding of how AI can enhance material selection and maintenance strategies, ultimately contributing to the sustainability and cultural significance of cultural centres.

## **RESULTS AND DISCUSSIONS**

The results of this study reveal that artificial intelligence significantly enhances material selection and maintenance planning in cultural centre design, particularly in tropical contexts such as Delta State, Nigeria. One of the most important findings is that AI-driven material selection improves durability and sustainability by integrating multiple performance parameters into the decision-making process. Traditional approaches often prioritize cost and availability, but AI systems evaluate structural performance, environmental impact, and lifecycle cost simultaneously. This ensures that materials chosen are not only affordable but also resilient under tropical climatic conditions characterized by heavy rainfall, humidity, and heat. For example, AI can identify materials with high resistance to moisture and biological degradation, thereby reducing premature deterioration and extending building lifespan. This finding is particularly relevant in Nigeria, where tropical climates accelerate material degradation, making advanced selection methods essential for cultural infrastructure.

Another key finding is the transformative role of AI in predictive maintenance. Machine learning models and digital twin technologies allow facility managers to anticipate material degradation and system failures before they occur. By analyzing historical data and real-time inputs from IoT sensors, AI systems forecast when specific components are likely to fail, enabling proactive interventions that minimize disruption and reduce costs. This predictive capability is especially valuable in cultural centres, which often host large public gatherings and cannot afford unexpected closures. For instance, a cultural centre equipped

with sensor-based monitoring can detect early signs of roof leakage or structural fatigue, allowing managers to intervene before the damage escalates into costly repairs. This shift from reactive to proactive maintenance represents a fundamental change in building management, ensuring uninterrupted functionality and safeguarding the cultural and social role of these buildings.

The study also highlights AI's contribution to lifecycle optimization. AI frameworks can simulate long-term material performance under varying environmental conditions, helping architects select materials that align with sustainability goals. For instance, AI can evaluate trade-offs between carbon footprint and lifecycle cost, ensuring that cultural centres contribute to environmental sustainability while remaining economically viable. This is especially relevant in Nigeria, where resource constraints demand cost-effective yet durable solutions. By embedding lifecycle assessment into material selection, AI ensures that cultural centres remain functional and sustainable over decades, reducing the financial and environmental burden of frequent repairs. This finding resonates with earlier studies that emphasized how poor consideration of lifecycle costs often leads to premature deterioration of public buildings, underscoring the importance of AI in bridging this gap.

Another significant result is the collaborative potential of AI-driven decision support systems. By providing shared platforms for analyzing material performance and maintenance needs, AI fosters integrated design and management practices. This collaborative approach ensures that cultural centres are conceived not only as architectural projects but as long-term cultural assets. For example, BIM platforms integrated with AI, such as Autodesk tools, allow architects, engineers, and facility managers to work together in real time, ensuring that design decisions are informed by both cultural symbolism and technical performance. Such collaboration strengthens the cultural and functional value of these buildings, making them more resilient to both environmental and social pressures.

The findings also demonstrate that AI-driven sustainability assessments bridge the gap between cultural expression and ecological responsibility. By simulating long-term material performance under varying climatic conditions, AI frameworks help architects select materials that align with sustainability goals. This ensures that cultural centres contribute to environmental sustainability while remaining economically viable. For example, AI can recommend materials that minimize carbon emissions during production while maximizing durability in humid environments, thereby aligning cultural architecture with global sustainability agendas. This is particularly important in Nigeria, where cultural centres often serve as multi-functional spaces that must withstand heavy usage and environmental stressors.

Finally, the results underscore the broader implications of AI integration in cultural centre design. By embedding AI into material selection and maintenance, cultural centres achieve higher levels of adaptability, sustainability, and resilience. They evolve into dynamic systems capable of responding to environmental changes, usage demands, and cultural shifts. This adaptability ensures that cultural centres remain relevant and functional over time, reinforcing their role as enduring symbols of heritage and community identity. The evidence indicates that adopting AI-driven material selection and predictive maintenance strategies will not only address current challenges in Nigerian cultural centres but also set a precedent for sustainable cultural infrastructure globally.

The combined results and discussion demonstrate that AI integration in cultural centre design and maintenance is not merely a technological enhancement but a strategic necessity. It improves durability, reduces costs, enhances sustainability, and strengthens cultural value. For Nigeria and similar contexts, adopting AI-driven strategies offers a pathway to overcoming longstanding challenges in public building performance. By moving beyond traditional, intuition-based approaches, AI provides data-driven insights that enhance both architectural quality and sustainability. This research therefore contributes to both academic discourse and practical solutions for sustainable cultural infrastructure, ensuring that cultural centres continue to serve as resilient and meaningful spaces for generations to come.

## **CONCLUSION AND RECOMMENDATIONS**

The study concludes that artificial intelligence represents a transformative force in cultural centre design and maintenance, particularly within tropical contexts such as Delta State, Nigeria. The findings demonstrate that AI-driven material selection enhances durability and sustainability by integrating multiple performance parameters—structural performance, environmental impact, and lifecycle cost—into a single decision-making framework. This ensures that materials chosen are not only affordable but also resilient

under climatic conditions characterized by heavy rainfall, humidity, and heat. By embedding AI into material selection, cultural centres can avoid premature deterioration and extend their lifespan, thereby preserving their cultural and social functions.

The research also establishes that AI-driven predictive maintenance is a strategic necessity for cultural centres. Machine learning models, digital twin technologies, and IoT sensors allow facility managers to anticipate material degradation and system failures before they occur. This proactive approach minimizes disruption, reduces costs, and ensures uninterrupted functionality. In contexts where cultural centres serve as multi-functional spaces for large public gatherings, predictive maintenance safeguards both safety and usability. The evidence shows that moving from reactive to proactive maintenance strategies is critical for sustaining cultural infrastructure in Nigeria.

Another important conclusion is that AI contributes significantly to lifecycle optimization. By simulating long-term material performance under varying environmental conditions, AI frameworks help architects select materials that align with sustainability goals while remaining economically viable. This integration of lifecycle assessment into design ensures that cultural centres remain functional and sustainable over decades, reducing financial and environmental burdens. In resource-constrained contexts such as Nigeria, lifecycle optimization is not only desirable but essential for ensuring that cultural centres remain resilient and cost-effective.

The study further concludes that AI-driven decision support systems enhance collaboration among architects, engineers, and facility managers. By providing shared platforms for analyzing material performance and maintenance needs, AI fosters integrated design and management practices. This collaborative approach strengthens the cultural and functional value of cultural centres, ensuring that they are conceived not only as architectural projects but as long-term cultural assets. Such collaboration is particularly important in Nigeria, where socio-cultural factors must be reconciled with technical performance.

Finally, the research underscores the broader implications of AI integration in cultural centre design. By embedding AI into material selection and maintenance, cultural centres achieve higher levels of adaptability, sustainability, and resilience. They evolve into dynamic systems capable of responding to environmental changes, usage demands, and cultural shifts. This adaptability ensures that cultural centres remain relevant and functional over time, reinforcing their role as enduring symbols of heritage and community identity.

Based on these conclusions, the following recommendations are proposed:

1. **For Architects:** Adopt AI-driven material selection frameworks that integrate performance, sustainability, and lifecycle cost. Use BIM platforms enhanced with AI to balance cultural symbolism with technical performance.
2. **For Facility Managers:** Implement predictive maintenance systems using machine learning, digital twins, and IoT sensors to anticipate failures and schedule proactive interventions.
3. **For Cultural Institutions:** Invest in AI-enabled infrastructure to ensure long-term durability and functionality of cultural centres, particularly in contexts of heavy usage and climatic stress.
4. **For Policymakers:** Develop policies that encourage the adoption of AI in public building projects, ensuring compliance with sustainability standards and reducing reliance on substandard materials.
5. **For Researchers:** Expand the discourse on AI applications in cultural architecture, focusing on material lifecycle management and predictive maintenance in tropical contexts.

In conclusion, AI integration in cultural centre design and maintenance is not merely a technological upgrade but a paradigm shift. It improves durability, reduces costs, enhances sustainability, and strengthens cultural value. For Nigeria and similar contexts, adopting AI-driven strategies offers a pathway to overcoming longstanding challenges in public building performance, ensuring that cultural centres continue to serve as resilient and meaningful spaces for generations to come.

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